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Complete Mix Activated Sludge Treatment of Citrus Process Wastes

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COMPLETE MIX ACTIVATED SLUDGE TREATMENT OF CITRUS PROCESS WASTES,

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EPA 12060 EZY 08/71

Winter Garden Citrus Products Cooperative, Winter Garden Florida

32787

Environmental Protection Agency

Water Pollution Control Research Series ~~No. 12060 EZY~~, August 1971, 120 p, 18 fig, 16 tab, 29 ref.

A full-scale, complete mixed activated sludge treatment system effectively treats concentrated wastewater from the Winter Garden Citrus Products Cooperative. This process has a BOD reduction capability of 99 percent; but it produces 0.5 to 0.6 pounds of waste sludge per pound of influent BOD. The efficiency was reduced by periodic foaming and solids carryover in the effluent caused by the unscheduled discharge of orange oil and peel press liquor to the treatment plant. Controlling the addition of nitrogen and phosphorus to the influent of the nutrient deficient wastewater effectively controlled effluent nitrogen and phosphorus concentrations. Waste sludge was mixed with citrus peel and processed as a cattle feed additive in the existing facilities. The waste activated sludge represented approximately 1.5 percent of the total cattle feed production on a dry weight basis. Treatment plant effluent was reused for barometric leg and cooling water and was then discharged. Annual treatment cost was estimated at $56,000 for investment costs (at 8% interest) and an average of approximately $60,000 for operating costs. However, reuse of the treated water also resulted in a $15,000 annual savings which was not reflected in the preceding cost analyses. (Lowry-Texas)

*Food processing industry, *Citrus fruits, *Activated sludge, Organic loading, Aeration, Kinetics, Lime, Chemical precipitation, Coagulation, Temperature, Nutrient requirements, Nitrogen, Phosphorus, Centrifugation, Sludge digestion, Hydrogen ion concentration, Operation and maintenance, Foaming, Water reuse, Cost analysis, Waste water treatment, Industrial waste

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COMPLETE MIX ACTIVATED SLUDGE TREATMENT OF CITRUS PROCESS WASTES

by
Winter Garden Citrus Products Cooperative
Winter Garden, Florida

for the
OFFICE OF RESEARCH & MONITORING
Environmental Protection Agency

EPA Grant No. 12060 EZY

August 1971

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $1.25

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ABSTRACT

A full-scale, complete mixed activated sludge treatment system effectively treats concentrated wastewater from the Winter Garden Citrus Products Cooperative. The system was designed for an average daily flow of 2.0 MGD and a BOD concentration of 2,000 mg/l. This process has a BOD reduction capability of 99 percent; but it produces 0.5 to 0.6 pounds of waste sludge per pound of influent BOD. Unscheduled discharge of orange oil and peel press liquor due to citrus processing plant problems caused periodic reductions in treatment efficiency due to foaming in the aeration system and solids carryover in the effluent.

Controlling the addition of nitrogen and phosphorus to the influent of the nutrient deficient wastewater effectively controlled effluent nitrogen and phosphorus concentrations. Control of pH was unnecessary with the exception of periods of unscheduled discharge of low pH peel press liquor.

Waste sludge was mixed with citrus peel and processed as a cattle feed additive in the existing facilities. The waste activated sludge represented approximately 1.5 percent of the total cattle feed production on a dry weight basis. Treatment plant effluent was reused for barometric leg and cooling water and was then discharged. Capital and operating cost of the system averaged 1.5¢ per box of fruit processed or 3.2¢ per pound BOD removed.

This report was submitted to fulfill EPA Grant No. 12060 EZY under partial sponsorship of the Water Quality Office, Environmental Protection Agency.

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SECTION I

CONCLUSIONS

1. The complete mixed activated sludge process can effectively remove more than 99 percent of the BOD from concentrated citrus processing wastewater.

2. When treating concentrated citrus wastewater by the complete mixed activated sludge process, the waste sludge handling facilities should be designed for 0.5 to 0.6 pounds of waste sludge per pound of BOD in the raw waste. The recommended design loading rate is 0.3 lbs BOD/lb MLSS.

3. Effluent nitrogen and phosphorus concentrations can be effectively regulated by controlling influent nitrogen and phosphorus concentrations added to the nutrient deficient wastewater.

4. Waste sludge can be mixed with citrus peel and processed in the existing rotary kiln dryers as a cattle feed additive. Waste activated sludge represented approximately 1.5 percent of the cattle feed production on a dry weight basis.

5. The effluent of the waste treatment plant can be used in the citrus processing plant for barometric leg and cooling water.

6. The discharge of orange oil and peel press liquor into the treatment plant tends to reduce treatment efficiency by causing foaming in and solids carryover from the activated sludge system. This is partially due to the toxicity of D-Limonene and other organic chemicals in orange oil and peel press liquor.

7. A solid bowl centrifuge proved to be ineffective for thickening either activated sludge alone or activated sludge mixed with lime sludge.

8. The capital and operating expense for the treatment system was 1.5¢ per box of fruit processed or 3.2¢ per pound of BOD removed during the 1969-70 season. These costs are directly affected by plant production as the plant does not operate at full capacity on a continuous basis nor does it operate but a few months per year.

9. The lime treatment unit proved to be unnecessary for nutrient control but proved to be an effective treatment process for removal of suspended and colloidal solids.

SECTION II

RECOMMENDATIONS

The exact causes of foaming in the activated sludge process treating citrus concentrate processing water need to be determined. If it is found that foam causing chemicals cannot be eliminated from the wastewater stream, methods of foam control need to be evaluated.

The factors which influence activated sludge settling rates need to be evaluated. Methods of increasing settling rates need to be developed.

The cost of recovering activated sludge as a cattle feed additive is directly related to the amount of moisture that must be removed in a rotary kiln dryer. More economical methods of sludge thickening and dewatering need to be developed.

This program has shown that large quantities of waste activated sludge can be recovered along with pressed citrus peel as a cattle feed additive. However, an investigation into the recovery of waste activated sludge alone as an animal feed is recommended due to its potential value as a high protein feed.

Further study of inplant processes should be conducted to reduce wastewater concentration and flow and prevent discharge of orange oil and peel press liquor into the waste treatment system.

Studies should be conducted to determine the effects of activated sludge organisms on receiving waters.

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SECTION III

INTRODUCTION

OBJECTIVES

The original objectives of the grant were:

> To determine the design and operating parameters for lime treatment of effluent from an activated sludge plant treating wastewater from a citrus processing plant. This included loading rate of lime treatment unit, lime doses required, and effect of starch on settling of lime sludge.
>
> To reuse the treated effluent in the citrus processing plant. To determine in which inplant processes the treated water was best suited for reuse.
>
> To determine the efficiency of lime treatment for removal of residual organic matter including nutrients. This included determining efficiency of removing BOD, COD, suspended solids, phosphorus and nitrogen.
>
> To determine design and operating parameters for thickening waste sludge by centrifugation.
>
> To determine suitability of waste sludge as a cattle feed additive.
>
> To provide an economical evaluation of the system.

The objectives listed above were those used to guide the research effort during the 1968-69 citrus season. After the 1968-69 season of operation, major revisions were made in the grant objectives. During the 1969-70 season, the use of the lime treatment unit was eliminated and all research associated with this process discontinued. Major emphasis was placed on demonstrating the complete mixed activated sludge process for treating concentrated citrus processing water and controlling effluent nutrient concentrations by controlling the addition of nutrients to the nutrient deficient wastewater. Research on the use of the centrifuge for dewatering sludge was de-emphasized because of its poor performance in thickening a combination of lime and activated sludge. With the exception of the previously mentioned changes, the objectives for the 1969-70 citrus processing season were the same as the 1968-69 season.

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BACKGROUND

Winter Garden Citrus Products Cooperative has been in operation at its present location in Winter Garden, Florida, for over 25 years. In early 1967, the Florida Department of Air and Water Pollution Control cited the Cooperative for discharging essentially untreated wastewater into Lake Apopka and stated that plans and a construction schedule for an adequate waste treatment system, including nutrient control, must be provided within approximately two months or an injunction would be sought to prevent the plant from operating during the 1967-68 season.

Prior to this time, the citrus processing plant had made considerable modifications inplant to segregate cooling and barometric leg water from contaminated wastewater. An attempt had been made to treat the concentrated wastewater during the 1966-67 season by chlorination. Treatment of citrus waste by chlorination proved ineffective and costly.

Environmental Engineering, Inc., was retained, after the citation was issued, to develop a waste treatment system and submit preliminary plans and a construction schedule. A review of existing waste treatment systems and previous research on citrus waste treatment was not encouraging. The only successful method of citrus waste treatment at that time was by land irrigation, such as that by Plymouth Citrus Products, Inc., of Plymouth, Florida, where all of their wastewater was being effectively disposed of by this method. This method presents a potential threat to ground water supplies, however, and requires large land areas which are seldom available. Land irrigation could not be used for the Winter Garden Citrus Products Cooperative because of the lack of available land. A waste treatment plant had been constructed in Leesburg, Florida, to treat the wastewater from the Minute Maid citrus processing plant along with the city sewage. This type of combined treatment could not be attempted at Winter Garden because the city wanted nothing to do with citrus wastewater.

A waste treatment plant was under construction in Auburndale, Florida, designed to treat the total flow of 30 MGD from two citrus processing plants; this included barometric leg and cooling water. This type of treatment process could not be used at Winter Garden because of the limitations of available land.

It was decided to test, on a laboratory scale, the complete mixed activated sludge process for treating the citrus processing wastewater from Winter Garden Citrus Products Cooperative. A small continuous feed activated sludge unit was operated for a period of four weeks in the laboratory. Results from this unit showed that, if the wastewater pH was controlled and supplemental N and P were added, the process would provide an effluent BOD less than 20 mg/l. Laboratory work on lime precipitation was conducted on a batch basis by coagulating effluent from the activated sludge process with a jar test machine.

Because of the time limitations set by the Florida Department of Air and Water Pollution Control, a pilot plant study was not performed. This meant that a full scale treatment plant had to be designed based only on laboratory data. The excess sludge handling and centrifuge dewatering systems were designed without any type of laboratory or pilot plant data.

DESCRIPTION OF CITRUS PROCESSING PLANT

Fruit is brought into Winter Garden Citrus Products Cooperative processing plant by large trailer trucks directly from the fields. The trailers are unloaded and the fruit graded and placed in storage bins. From the storage bins, fruit is moved as required by conveyor belt to the fruit washers where dirt, sand, and other foreign matter is washed from the fruit surface. This is the first source of wastewater in the processing plant (see Figure 1). This wash water is passed through a screen, as is all wastewater, and discharged directly to the waste treatment plant.

The fruit is again graded, then sized and moved to the extraction room. Three products, juice, peel, and cold press oil, result from the extraction process. The extraction process is a major source of wastewater, as the machines must be cleaned regularly with NaOH and detergent to prevent a bacterial buildup. This wash water is screened and discharged to the waste treatment plant.

Cold press oil, a mixture of orange oil and water, comes from the extractors and is passed through centrifuges for removal of the orange oil. The water discharged from the centrifuges still contains a quantity of oil and is normally evaporated as it has an exceedingly high BOD. However, during times of overloading or mechanical failure, it can find its way into the wastewater stream. This waste is toxic in high concentrations and can cause severe foaming; therefore, it can cause problems with the operation of an activated sludge process.

Juice extracted from the fruit is concentrated by vacuum evaporation then canned or placed in 55 gallon drums for storage and later canning. Condensor water from the evaporators and wash water containing citrus juice, NaOH, and detergent from the canning operation are the major sources of wastewater going to the waste treatment plant from the juice processing operation. After the juice has been put in either drums or cans, it is cooled, then placed in cold storage for later shipping. Cooling water for refrigeration equipment is discharged untreated directly to Lake Apopka.

The third product from the extraction process is citrus peel. Peel from the extraction process is moved by screw conveyor to the peel bin. Drippings from the peel bin are pumped to the peel press liquor storage tank. Peel is taken from the peel bin, has lime added to it,

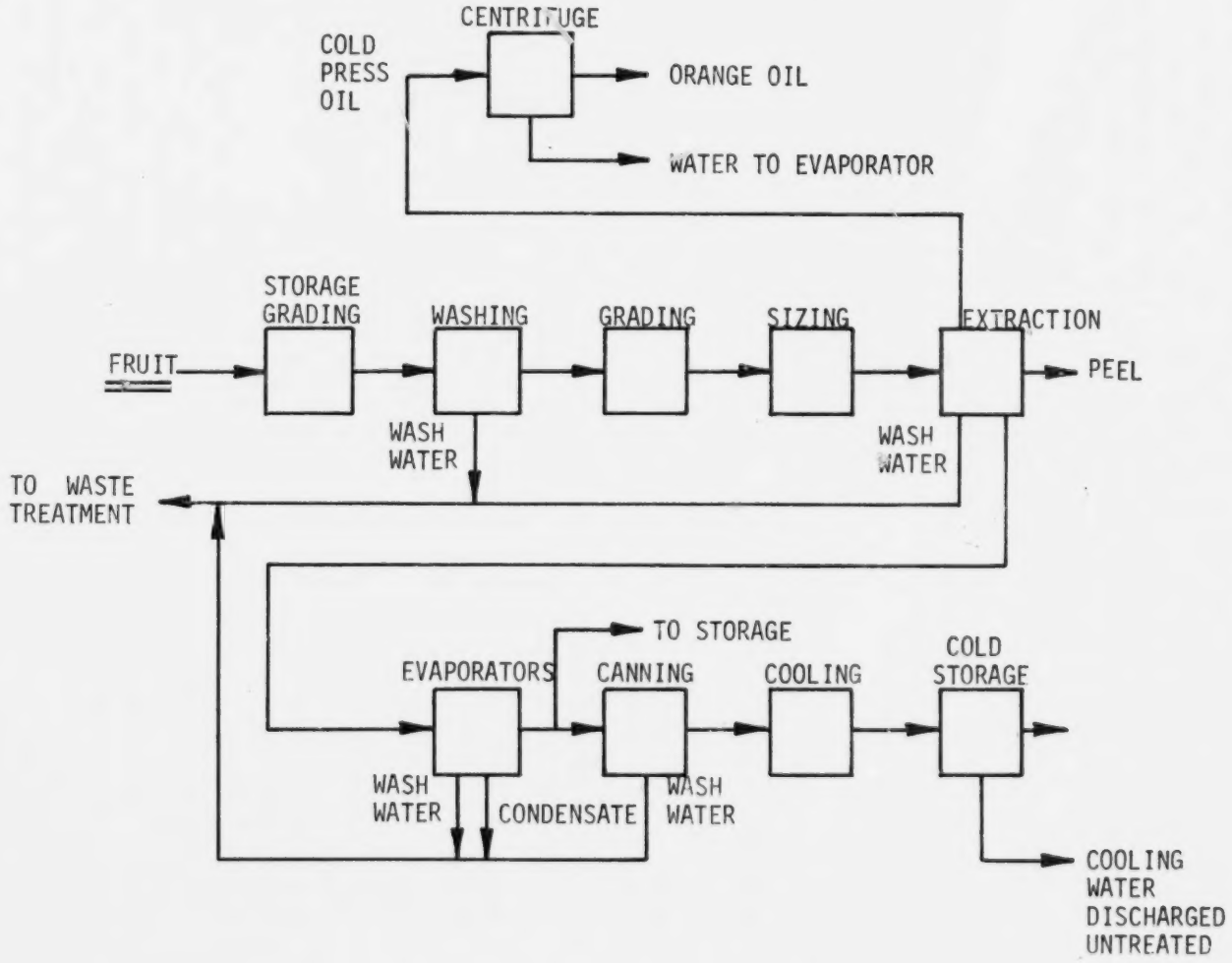

FIGURE 1 PROCESS FLOW DIAGRAM

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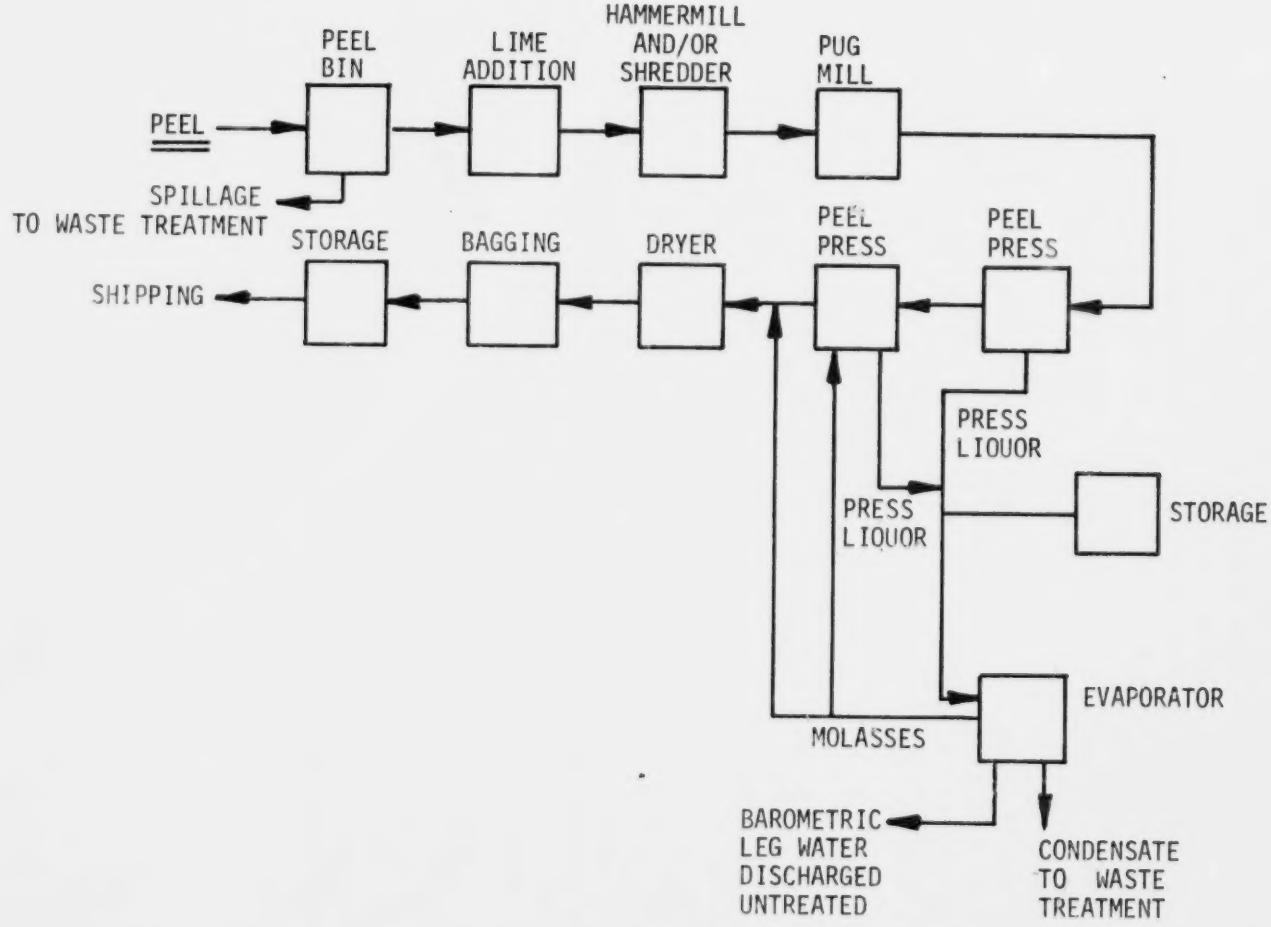


FIGURE 1 (CONTINUED)
PROCESS FLOW DIAGRAM

and then is passed through a hammermill or shredder. Next the peel is run through a pug mill for mixing then pressed for the first time. Peel press liquor is pumped from the press directly to a vacuum evaporator or to storage for later evaporation. Condensate from the molasses evaporator is discharged to the waste treatment plant. Barometric water is discharged directly to Lake Apopka untreated as its BOD is less than 10 mg/l. Molasses from the evaporator is put back on the peel for recovery as a cattle feed additive or sold directly. It is cheaper to remove peel press liquor from citrus and evaporate it to molasses in a vacuum evaporator than to attempt to dry the peel in the rotary dryers. After the peel is dried, it is bagged and placed in storage for later shipment. Approximately 350 tons of dried peel per day are produced for sale as a cattle feed additive at the Winter Garden plant.

Two potential wastewater sources are from the peel press liquor and oil mill water. Both of these wastewaters are normally concentrated by vacuum evaporation and placed on pressed peel for recovery as a cattle feed additive. These two wastes represent a large volume of liquid and place a heavy load on the evaporators. In the event that an evaporator becomes inoperative or cannot handle the volume produced, these wastes overflow into the waste treatment system. Both the oil mill water and peel press liquor have BOD's approaching 100,000 mg/l and contain chemicals toxic to the activated sludge process. Frequently, large volumes of these wastes were discharged with devastating results on the waste treatment plant. Every effort should be made to prevent these wastes from entering the waste treatment system as they can completely upset the treatment process.

It is extremely difficult to characterize the chemical composition and flow rates of each of the waste streams. Plant production depends upon the availability of fruit and varies widely during the processing season. The Winter Garden Citrus plant may process from 10,000 to 60,000 boxes of fruit per day. Table 1 shows typical flows and BOD concentrations during processing at plant capacity.

TABLE 1

INPLANT WASTEWATER STREAMS

Source	BOD (mg/l)	FLOW (GPD)	Comments
Fruit Wash Water	100 - 600	150,000	Contains dirt and grit. Characteristics depend upon weather conditions.
Extraction Room	1000 - 10,000	100,000	Intermittent wash water.
Juice Condenser Water	300 - 600	450,000	No suspended solids.
Canning Room	1000 - 10,000	40,000	Intermittent wash water.
Molasses Condenser Water	500 - 1000	350,000	No suspended solids.
Peel Press Liquor	100,000	--	Spills
Centrate Water From Oil Centrifuge	25,000	--	Spills

DESCRIPTION OF TREATMENT PLANT (1968-69 Season)

Figure 2 shows a schematic of the Winter Garden waste treatment plant as originally designed and operated during the 1968-69 season. Plant design was based on a flow of 2 MGD and a BOD of 2000 mg/l. Design criteria were based on laboratory tests and are shown below:

0.4 lbs BOD/lb MLSS at 3500 MLSS

Nutrient Addition -- BOD:N:P of 100:20:1

O_2 Uptake Rate -- 50 mg/l per hour maximum

Mechanical Aerator Efficiency -- 2.2 lbs O_2/H.P.Hr. at 20°C

Clarifier Surface Loading Rate -- 700 Gal/ft^2/day

Lime Feed Rate -- 350 mg/l

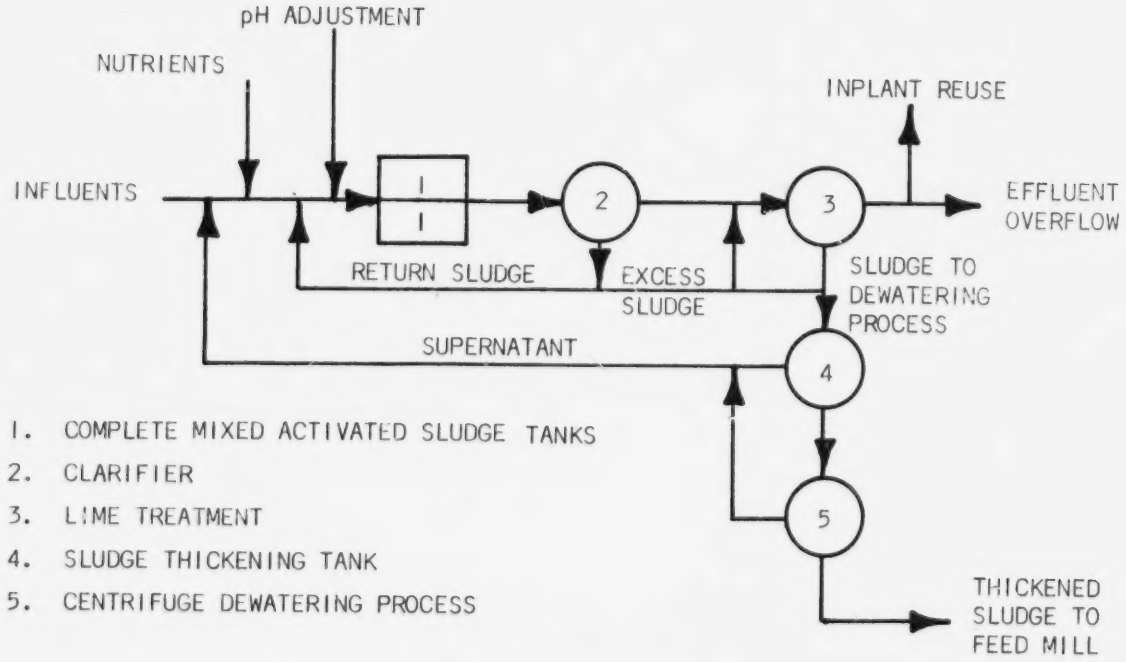
Waste Lime Sludge -- 3 tons/day maximum

Waste Activated Sludge -- 0.4 lbs/lb BOD removed

Nutrients were added in the form of phosphoric acid and anhydrous ammonia. The pH was controlled with NaOH as required. Pre-screened wastewater was pumped into two concrete aeration basins 144 feet in diameter. Side water depth was approximately 12 feet. The original design called for four 75 H.P. floating mechanical aerators, but only three were installed due to the flow rate being less than was originally expected. The aeration basins were designed so they could be operated in series or parallel.

Effluent from the aeration basins flowed to a clarifier from which return sludge was pumped back into the influent pipe to the aeration basins. Effluent from the clarifier flowed to the lime treatment tank then either back to the citrus plant for reuse or directly to Lake Apopka. Waste sludge from the clarifier and lime treatment tank were discharged to a wet well then pumped to a surge tank in the citrus plant. The surge tank also served as a sludge thickening tank, although it contained no mechanical thickening equipment. Thickened sludge from the bottom of the surge tank was pumped to a solid bowl centrifuge or placed directly on the pressed peel. The supernatant liquor was returned to the plant influent and the solids cake mixed with pressed citrus peel for recovery as a cattle feed additive.

The unique features of the waste treatment system design were several. It was the only treatment plant in Florida treating concentrated citrus processing plant wastewater alone. The effluent from the activated sludge plant was further treated for residual organic and nutrient removal by lime treatment. All effluent from the treatment plant could be reused in the citrus plant and all waste sludge was to be recovered as a cattle feed additive.



1. COMPLETE MIXED ACTIVATED SLUDGE TANKS
2. CLARIFIER
3. LIME TREATMENT
4. SLUDGE THICKENING TANK
5. CENTRIFUGE DEWATERING PROCESS

FIGURE 2 WASTEWATER TREATMENT SYSTEM

SECTION IV

1968-69 CITRUS PROCESSING SEASON

WASTEWATER FLOW AND FRUIT PROCESSED

During the 1968-69 citrus processing season, a daily record was kept on the number of boxes processed and the volume of wastewater treated. A record was kept also of the type fruit processed, i.e. grapefruit or oranges. Wastewater flow was measured in a Parshall flume and recorded on a flow chart as well as a totalizer meter.

Table 2 shows the average number and types of boxes of fruit processed and the average wastewater flow per day for each month of operation during the season. These averages include many days in which no fruit was processed. Depending upon the availability of fruit, a processing plant may either not operate at all, or operate one, two, or three shifts per day up to seven days a week. Wastewater flow was not continuous throughout the season as frequently the plant was not in full operation during the weekend and only clean-up crews were working. A complete tabulation of daily wastewater flow and fruit processed may be found in Table A-1 of the Appendix.

TABLE 2

AVERAGE WASTEWATER FLOW AND FRUIT PROCESSED

Month 1969	Average Daily Flow MGD	Range MGD	Average Daily Fruit Processed 1000 Boxes*	Range 1000 Boxes
January	0.98	0.4 - 1.3	47.2	0.0 - 60.9
February	0.87	0.3 - 1.4	41.2	0.0 - 57.2
March	0.61	0.1 - 1.2	16.1	0.0 - 47.4
April	0.87	0.0 - 1.3	24.9	0.0 - 53.4
May	1.10	0.0 - 1.5	44.0	0.0 - 63.3
June	1.00	0.0 - 1.5	36.4	0.0 - 61.5

* one box is 90 pounds of fruit

Data collected shows that for every box of fruit processed (90 pounds of fruit) approximately 25 gallons of wastewater must be treated. This wastewater had an average BOD of 1,170 mg/l, therefore, approximately 0.25 pounds of BOD for each box of fruit processed must be treated. Data of this type should be used with caution when applying it to other citrus processing plants as inplant process and water uses vary widely from plant to plant.

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TABLE 2s

STATISTICAL ANALYSIS OF WASTEWATER FLOW AND FRUIT PROCESSED

PARAMETER	DATA POINTS	MEAN	STANDARD DEVIATION
Wastewater Flow Daily Values	157	0.89 MGD	0.42 MGD
Wastewater Flow Monthly Averages	6	0.90 MGD	0.15 MGD
1000 Boxes of Fruit Processed Daily Values	157	33.2	22.9
1000 Boxes of Fruit Processed Monthly Averages	6	35.0	11.0

Number of days of zero flow = 6
Number of days of no fruit production = 34

NUTRIENT ADDITION AND pH CONTROL

The original waste treatment plant design called for nutrient addition in the form of anhydrous ammonia and phosphoric acid. Control of pH was to be by addition of NaOH because of the expected low pH of the wastewater. Ammonia and phosphoric acid were added by variable discharge pumps set manually. Initially, there was no good method available to control the addition of nutrients to correspond to the wide fluctuations of wastewater flow and strength because of the lack of a quick method for determining nutrients in the treatment plant effluent.

Samples were collected and sent to Gainesville for nutrient analysis in an auto-analyzer. By the time data was available, several days had passed making this method unacceptable for controlling nutrient addition. It became apparent that a simple test method would have to be provided for the operators to run during plant operation. Test kits were obtained which allowed the operators to run orthophosphate and ammonia on each shift in a matter of minutes. These tests became a part of the routine operation and an attempt was made to keep the ammonia and orthophosphate in the complete mixed activated sludge aeration tank at approximately 1.0 mg/l each by increasing or decreasing the nutrient addition to the influent. Sampling the effluent from the sludge clarifier will give erroneous results because the activated sludge will release excess phosphate if held in the clarifier too long. Therefore, nutrient samples must be collected from the aeration tank.

This method proved successful once the cause of the foaming problem in the activated sludge process was determined. Table A-2 in the Appendix gives the average pounds per day of nitrogen and phosphorus added to the influent for each month. Table A-3 in the Appendix gives the concentrations in monthly averages of daily nitrogen and phosphorus in the influent after nutrient addition, and in the biologically treated effluent. The last few weeks of the citrus season, when the waste treatment plant was working perfectly, the ammonia nitrogen was usually less than 0.5 mg/l, and the orthophosphate less than 1.0 mg/l. During this period, the BOD to N ratio was 18 to 1 and the BOD to P ratio was 80 to 1. Therefore, when any nutrient deficient waste is being treated by the complete mixed activated sludge process, the nutrient addition and the resulting nutrient concentrations in the effluent can be controlled by frequent nutrient analyses in the aeration tank.

Wastewater pH control was not found to be a problem as the pH was much higher than expected, ranging from 7.0 to 8.5. This was partly due to inplant clean-up with NaOH, and also the recycling of lime to the influent from the sludge thickening tank and centrifuge. The only time NaOH had to be added to the treatment system was after an unusually large amount of low pH (3.5 -- 4.5) peel press liquor had been discharged to the waste treatment plant lowering the pH in the activated sludge process.

ACTIVATED SLUDGE PROCESS OPERATIONAL PROBLEMS

Operational problems were caused by: (1) discharge of peel press liquor, (2) discharge of water from the orange oil recovery system, and (3) inability to waste sludge as desired. The first two problems were the most serious. It was not unusual to receive 25,000 to 50,000 gallons of press liquor over a short period of time. Peel press liquor has a BOD of around 100,000 mg/l and contains orange oil and d-Limonene which, in high concentrations, are toxic to the activated sludge process and also cause foaming. In general, when a slug of peel press liquor was received, the aeration tank D.O. was lowered drastically, the S.V.I. decreased and foaming occurred. This resulted in solids overflowing the weirs into the lime treatment tank significantly reducing the treatment efficiency.

Foaming was perhaps the major problem experienced with the activated sludge process. Foaming occurred a considerable portion of the citrus season to varying degrees and caused a reduction in treatment efficiency for both the activated sludge process and the lime treatment process. It was only during the latter part of the season that the major cause of foaming was determined to be small quantities of water from the oil recovery process being discharged into the treatment plant on a continuous basis. As soon as all of this waste stream was diverted to the evaporators and no excess press liquor was discharged, the activated sludge process performed as designed.

AERATION TANK ANALYSES

Every two hours samples were collected from both aeration tanks to determine the D.O., pH, MLSS, and SVI. Table 3 contains monthly averages of these results. Dissolved oxygen concentrations varied widely during the research period depending upon the load applied to the treatment plant and concentration of MLSS carried in the aeration tanks. At times, the D.O. of the aeration tanks would be decreased below the desirable minimum of 1.0 mg/l. This was due to the combination of high solids concentration in the tanks and reduced oxygen transfer efficiency of the mechanical surface aerators as a result of foam.

The pH of the mixed liquor varied from 7.0 to 8.3. Only when large volumes of press liquor were discharged did the pH tend to decrease and require NaOH to be added. The aeration basins were well buffered and were able to tolerate considerable variation in influent pH without marked influence because of the tremendous dilution capacity of the complete mixed activated sludge process and its buffering capacity.

TABLE 3

AVERAGE AERATION TANK ANALYSES

	North Aeration Tank				South Aeration Tank			
1969	MLSS mg/l	SVI	D.O. mg/l	pH	MLSS mg/l	SVI	D.O. mg/l	pH
January	1367	---	---	7.3	1382	---	5.2	7.8
February	2999	---	5.0	7.7	2990	---	4.5	7.7
March	4344	118	5.2	7.8	3884	133	6.2	7.9
April	3228	337	3.8	7.6	3092	334	3.9	7.8
May	3714	296	2.2	7.6	3945	262	1.7	7.6
June	5566	163	2.7	7.7	5916	161	2.4	7.7
July	5350	176	4.2	7.8	5550	171	3.9	7.9

TABLE 3s

STATISTICAL ANALYSIS OF AERATION TANK ANALYSES

		North Aeration Tank			South Aeration Tank		
		Data Points	Mean	Standard Deviation	Data Points	Mean	Standard Deviation
MLSS mg/l	Daily Figures	142	3987	1592	138	3992	1596
	Monthly Averages	7	3795	1348	7	3823	1443
SVI	Daily Figures	97	231	155	82	229	120
	Monthly Averages	5	218	84	5	212	75
D.O. mg/l	Daily Figures	150	3.76	2.09	151	3.72	2.49
	Monthly Averages	6	3.85	1.10	7	3.97	1.43
pH	Daily Figures	154	7.68	0.30	154	7.69	0.26
	Monthly Averages	7	7.64	0.16	7	7.77	0.10

The SVI, which is a measure of the settling rate of the sludge, varied from 54 to over 800. It is interesting to note that, in general, lower SVI values were found when the loading rate was increased by the addition of peel press liquor. SVI values increased to excessive values when water containing emulsified orange oil discharged to the treatment plant and foaming problems resulted. After the orange oil discharge was stopped, the SVI was consistently less than 200. This allowed separation of the MLSS from the treated waste and resulted in a very clear effluent.

MLSS varied considerably during the citrus season. Initially, the aeration tanks were filled with well water and seeded with activated sludge from the Leesburg plant. No problem was experienced during start-up other than a light foam which disappeared as the MLSS concentration increased. MLSS concentrations increased to a high of 7,480 mg/l without adverse effects. The major problem with controlling solids concentrations was the inability to waste solids as desired. As long as orange oil was not discharged to the treatment process and the SVI remained below 200, MLSS concentrations of 4,000 to 5,000 mg/l were carried with no difficulty. When solid concentrations of this magnitude are carried, it is mandatory that adequate aeration equipment be provided as well as sufficient clarification capacity.

ACTIVATED SLUDGE PROCESS TREATMENT EFFICIENCY AND LOADING RATES

As previously mentioned, the activated sludge portion of the waste treatment plant was designed to treat 2.0 MGD with a BOD of 2,000 mg/l. Aeration was to be provided by four 75 H.P. mechanical surface aerators in each of the two aerator tanks. Only three 75 H.P. aerators were provided for each tank, however, because the load was expected to be less than originally anticipated. The maximum and minimum flows occurring in the plant were 1.5 and 0.0 MGD, respectively. The maximum and minimum BOD concentrations applied were 3,300 and 270 mg/l, respectively.

Activated sludge loading rates varied from 0.014 to 0.378 pounds of BOD per pound of MLSS. The average loading rate during the citrus season was 0.143 pounds of BOD per pound of MLSS, which is within the limits of the loading rates of the extended aeration process.

Maximum and minimum BOD concentrations in the effluent were 129 and 2.0 mg/l, respectively. The 129 mg/l maximum, however, was due to solids carryover from the clarifier. Only two 24-hour effluent composites had greater than 100 mg/l BOD. Figures C3 and C4 in the Appendix show views of an aeration tank and the clarifier. Table A-4 in the Appendix presents monthly averages of the influent and effluent BOD, COD, and solids analyses. The monthly averages of the loading rates are shown in Table 4. The loading rates are presented in more

detail in Table A-5 in the Appendix. Figure 3 shows the semimonthly average influent and effluent BOD concentrations. Figure 4 shows the semimonthly average influent and effluent COD concentrations. Figure 5 shows the semimonthly average sludge loading rates.

The influent and effluent BOD concentrations over the entire season averaged 1170 and 30 mg/l, respectively, for an average efficiency of 97.5 percent. However, many problems experienced during the season depressed the efficiency to this figure. A more realistic picture of what the treatment plant can accomplish occurred in the latter part of the season, during the period from June 4, to July 2, 1969, when the foaming problem had been solved. BOD values of the influent and effluent averaged 1000 and 7 mg/l, respectively, during these four weeks for a treatment efficiency of 99.3 percent.

Table A-4 shows that the suspended solids in the effluent of the biological treatment process were exceedingly high during a good portion of the citrus processing season. This was attributed to two factors. The first was that, in the original design concept, waste activated sludge was to be wasted over the weirs and recovered with waste lime sludge. It soon became evident that the lime tank was incapable of removing large quantities of waste sludge, therefore, activated sludge was wasted directly to the wet well bypassing the lime tank. The second major factor was foaming. During a considerable portion of the citrus season a heavy layer of foam existed on the aeration tanks. This foam, at times, reached a depth of several feet. It was carried through the clarifier to the lime treatment tank. The sludge clarifier was designed without a surface skimmer which allowed any floating matter to overlfow the weir. This greatly increased the suspended solids in the biologically treated effluent as, normally, the foam would be skimmed and returned to the aeration tanks. The average suspended solids in the clarifier effluent during the period from June 4 through July 2, when the complete plant was operating properly, was only 12 mg/l.

WASTE ACTIVATED SLUDGE

Table 5 gives the monthly average volume per day of waste activated sludge which was discharged to control the concentration of the MLSS in the aeration basins. Waste activated sludge was mixed with waste lime sludge in a wet well and pumped to a holding tank in the citrus processing plant. Frequently, a portion of this waste sludge was recycled to the treatment plant because of the inability of the waste sludge facilities to handle the solids discharged. This recycling of solids made it almost impossible to determine quantities of waste sludge produced, as there were no facilities for measuring the volume and concentration of the recycled solids.

TABLE 4

AVERAGE ACTIVATED SLUDGE PROCESS LOADING RATES

MONTH 1969	BOD mg/l	Flow Rate MGD	Average MLSS (mg/l)	lbs BOD/ lbs MLSS
January	827	1.2	1496	0.234
February	1438	1.0	3063	0.185
March	1459	0.9	3940	0.138
April	836	1.1	3349	0.118
May	1139	1.3	4041	0.139
June	1021	1.3	5508	0.079

TABLE 4s

STATISTICAL ANALYSIS OF ACTIVATED SLUDGE MONTHLY

AVERAGE PROCESS LOADING RATES

	Data Points	Mean	Standard Deviation
BOD mg/l	6	1120	256
Flow Rate MGD	6	1.1	0.1
Average MLSS (mg/l)	6	3566	1206
lbs BOD/ lbs MLSS	6	0.149	0.049

TABLE 5

WASTE SLUDGE BLOWDOWN

MONTH 1969	ACTIVATED SLUDGE 1000 GPD	LIME SLUDGE 1000 GPD
January	10.0	0.0
February	39.9	14.2
March	46.4	42.4
April	53.3	19.4
May	86.5	13.5
June	85.5	17.9

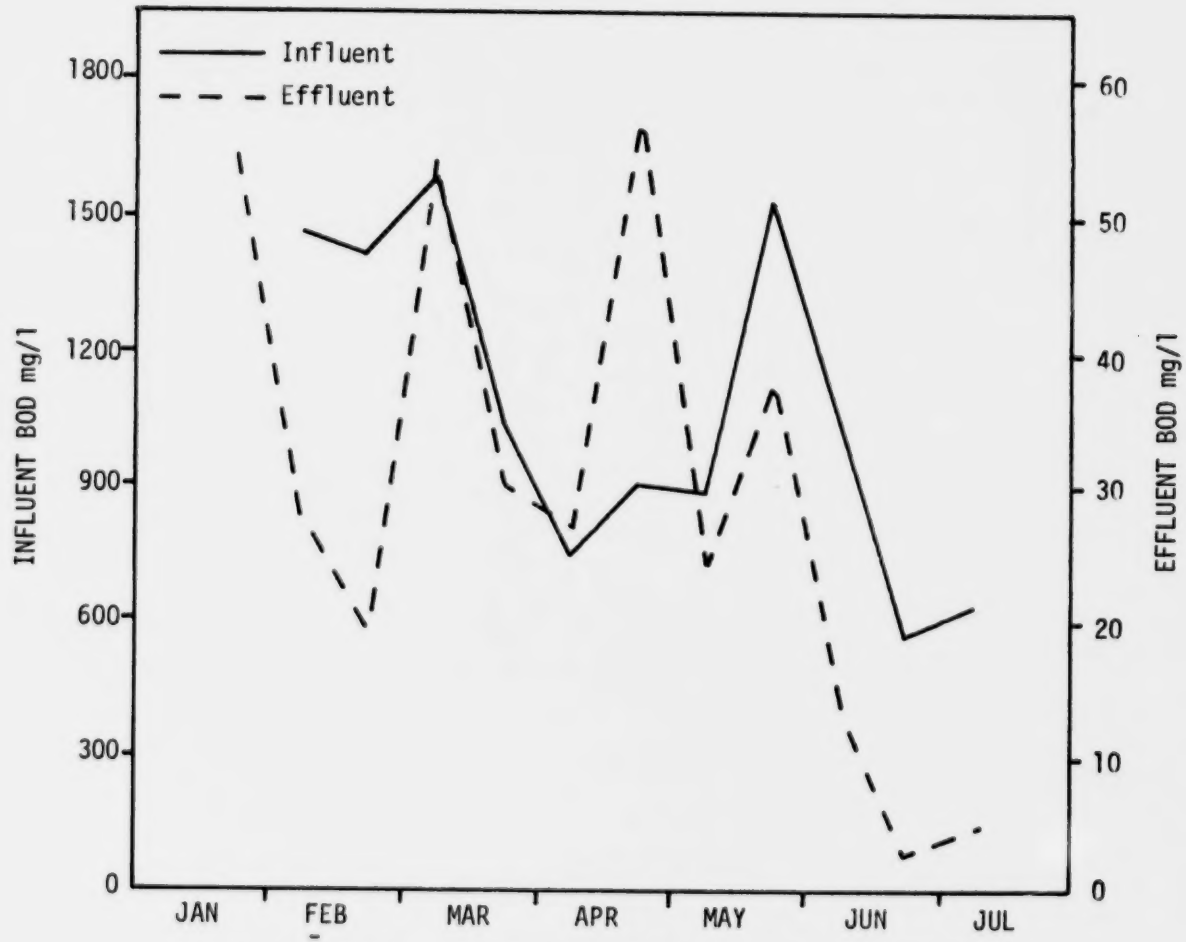


FIGURE 3 - INFLUENT AND BIOLOGICALLY TREATED EFFLUENT BOD
(SEMIMONTHLY AVERAGES - 1968-69 SEASON)

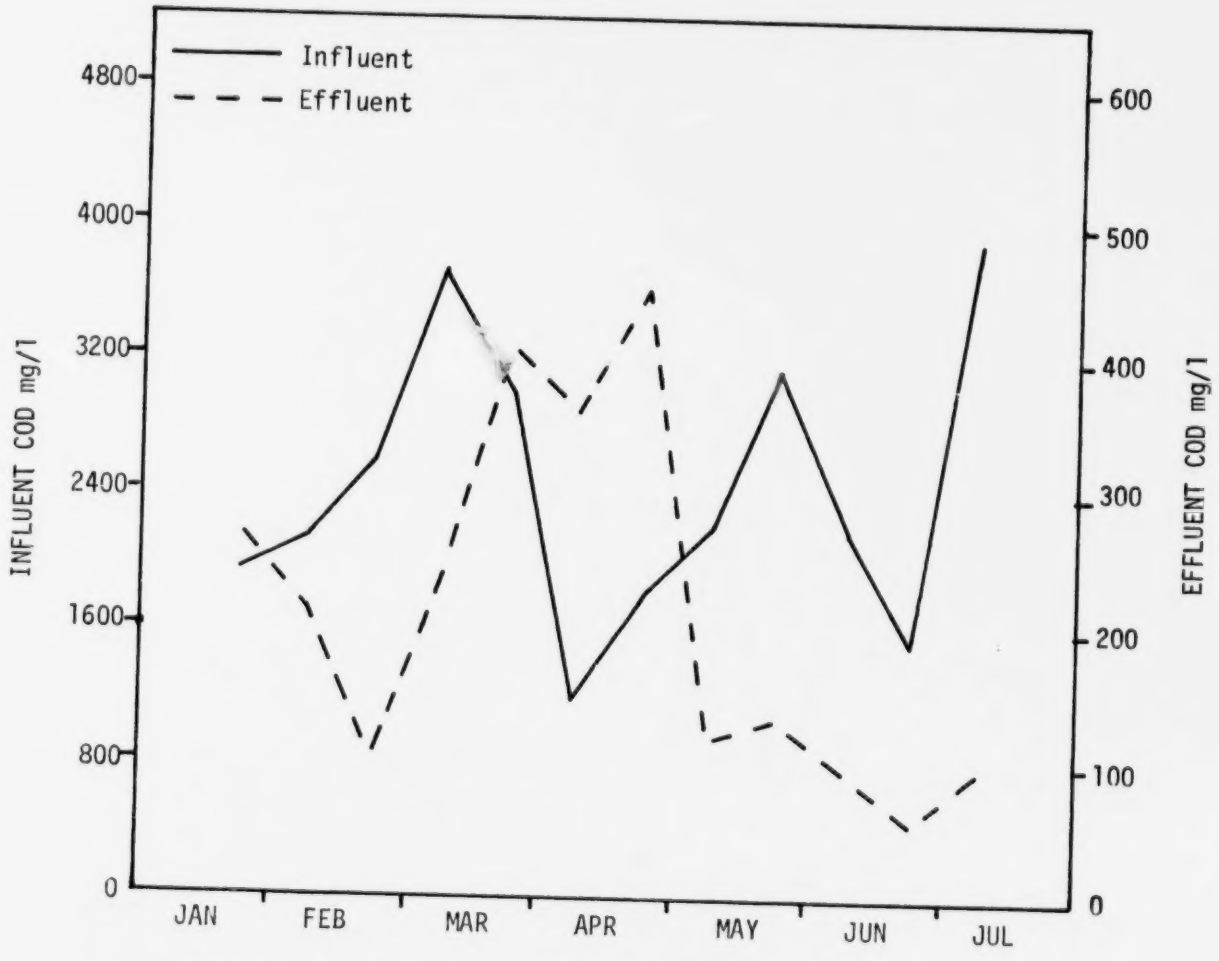


FIGURE 4 - INFLUENT AND BIOLOGICALLY TREATED EFFLUENT COD
(SEMIMONTHLY AVERAGES - 1968-69 SEASON)

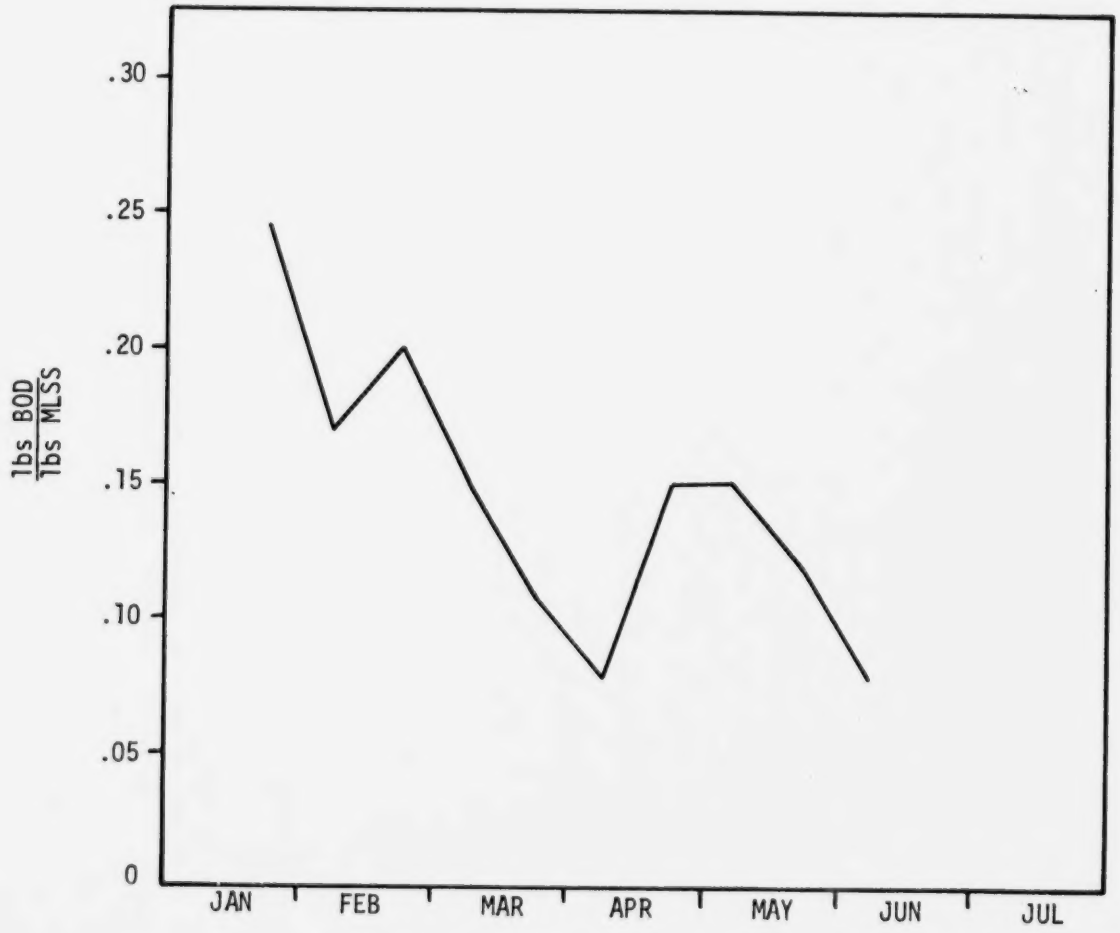


FIGURE 5 - ACTIVATED SLUDGE PROCESS LOADING RATES
SEMIMONTHLY AVERAGES - 1968-69 SEASON

Table 6 shows the variation in the concentration of the waste activated sludge solids. Two main factors influence the solids concentration of the waste sludge. The SVI is a major factor in the concentration of solids. The lower the SVI, the higher the concentration of solids will be in the bottom of a clarifier and, of course, the higher the SVI the lower the concentration. Sludge concentration is also a function of the time the solids are allowed to concentrate in the clarifier. The higher the sludge return rate is, the lower the solids concentration in the return sludge and waste sludge.

During the period 6/2/69 through 6/12/69, the activated sludge process was performing exceptionally well. A close check was made to determine the amount of excess solids produced during this period. There was no sludge recycled from the processing plant during this period. Table 7 gives the results of these tests. An average of 1000 gallons per hour of 1.34 percent sludge solids was blown down. At an average loading rate of 0.08 pounds of BOD/lb MLSS, 0.32 pounds of solids/lb BOD were wasted. Perhaps this is the key factor in designing activated sludge plants for concentrated citrus waste. This is a high solids build-up rate at such a low loading rate. This, of course, includes non-degradable suspended solids in the influent, solids build-up from BOD removal, and loss of solids through endogenous respiration. If adequate facilities are not provided to handle the excess sludge, the waste treatment system cannot function properly.

LIME TREATMENT PROCESS OPERATIONAL PROBLEMS

There were a variety of operational problems associated with the lime treatment tank. The lime treatment unit was initially designed to remove all waste activated sludge with the precipitated $CaCO_3$ sludge. However, the lime sludge settled separately from the waste activated sludge which prevented removal of large quantities of activated sludge. If the heavier lime sludge was removed fast enough to keep the activated sludge from going over the weirs, all of the lime sludge was quickly removed leaving no lime sludge blanket. This problem was solved by wasting the excess activated sludge directly to the sludge wet well. The two sludges mixed to some degree in the wet well, and were then pumped to the citrus processing plant for recovery as a cattle feed additive.

Although activated sludge was not intentionally discharged to the lime tank after the first few weeks of operation, unintentional discharge of solids occurred during most of the citrus season with the exception of the last few weeks of operation. The main reason for this was the foam carry-over from the aeration tanks. The inability to produce a clear effluent was the major result of this solids carry-over. This significantly affected the treatment efficiency of the lime treatment process. Only during the last few weeks of operation after the wastewater containing orange oil was removed from the treatment plant did the lime tank produce an acceptable and clear effluent. The lime treatment was operated over a wide range of pH values; however, a pH of 10.5 proved most effective.

TABLE 6

WASTE ACTIVATED SLUDGE SOLIDS

Date	Percent Solids	Date	Percent Solids
2/21/69	1.78	6/2/69	1.13
2/21/69	0.98	6/3/69	1.37
3/7/69	0.86	6/4/69	1.04
3/8/69	0.40	6/5/69	1.27
4/7/69	1.17	6/6/69	1.36
4/14/69	0.86	6/7/69	1.38
4/21/69	1.29	6/8/69	5.62
4/22/69	1.01	6/9/69	1.75
5/5/69	0.81	6/10/69	1.35
5/15/69	1.42	6/11/69	1.41
5/16/69	1.22	6/12/69	1.37
5/17/69	2.32	6/13/69	1.48
5/18/69	0.70	6/14/69	1.54
5/19/69	2.02	6/15/59	0.67
5/20/69	6.06	6/16/69	1.39
5/21/69	3.52	6/17/69	1.55
5/22/69	1.51	6/18/69	1.53
5/23/69	1.74	6/19/69	1.41
5/24/69	0.53	6/20/69	2.07
5/25/69	4.14	6/21/69	1.70
5/26/69	0.91	6/22/69	1.01
5/27/69	1.18	6/23/69	1.18
5/28/69	0.94	6/24/69	4.76
5/29/69	0.85	6/25/69	1.17
5/30/69	0.18	6/26/69	3.79
5/31/69	0.65	6/27/69	1.32
6/1/69	0.85		

Data Points = 53

Mean = 1.61

Standard Deviation = 1.20

TABLE 7

SLUDGE PRODUCTION

Date	Act.Sludge B.D. Rate GPH	% Solids	Lbs Solids	Lbs BOD	Lbs Solids / Lbs BOD	Lbs BOD / Lbs MLSS
6/2/69	1100	1.13	2420	4400	.55	.042
6/3/69	1100	1.37	3000	6800	.44	.059
6/4/69	1100	1.04	2280	7500	.30	.065
6/5/69	1100	1.27	2700	10,700	.25	.083
6/6/69	1100	1.36	3000	25,200	.12	.184
6/7/69	900	1.38	2480	27,400	.09	.169
6/9/69	1400	1.75	4900	9300	.53	.078
6/10/69	800	1.35	2160	5700	.38	.044
6/11/69	800	1.41	2240	9700	.22	.073
6/12/69	800	1.37	2180	8400	.26	.059

TABLE 7s

STATISTICAL ANALYSIS OF SLUDGE PRODUCTION

	Data Points	Mean	Standard Deviation
Act. Sludge B.D. Rate, GPH	10	1,020	183
% Solids	10	1.34	0.18
Lbs Solids	10	2,736	780
Lbs BOD	10	11,510	7,622
Lbs Solids / Lbs BOD	10	0.31	0.15
Lbs BOD / Lbs MLSS	10	0.086	0.047

A series of coagulant aids were tested in dosages recommended by the manufacturers. Starch, the first aid tested, proved to be useless because of the high concentration of activated sludge solids entering the lime tank. Alum was tried with similar results. Only after using CaO alone at a high pH was any significant results obtained in settling wastewater containing high concentrations of activated sludge. This was probably due to the precipitation of $Mg(OH)_2$ at the higher pH. No problem was experienced with obtaining a clear effluent as long as the effluent from the sludge clarifier contained a low solids concentration.

LIME TANK SOLIDS ANALYSES

The normal method used to control a lime treatment unit in a water softening plant is to determine the concentration of solids in the upper and lower draft tube, the location of the sludge blanket, and the pH of the effluent. As long as the sludge blanket is not overflowing the weirs, its location is not too meaningful. The concentration of solids in the upper and lower draft tube gives a measure of the solids contained in the solids contact area.

Throughout most of the citrus processing season activated sludge entering the lime treatment unit negated any attempt to correlate solids data with operation. Therefore, the lime unit was operated almost completely by controlling the pH of the effluent and attempting to blow down solids fast enough to prevent the blanket from going over the weirs.

During the last few weeks of operation, when the treatment plant was working as designed, it was impossible to keep a high solids concentration in the draft tube. This was because the lime solids settled rapidly when no activated sludge was present in the influent. The effluent was sparkling clear and had the appearance of drinking water.

TREATMENT EFFICIENCY OF THE LIME UNIT FOR BOD, COD AND SOLIDS REMOVAL

The chemical data obtained during the 1968-69 season cannot be used as a basis for judging the efficiency of lime treatment of an activated sludge effluent. This is because the waste treatment plant was not operating properly on a continuous basis until the last few weeks of the season. After the foaming problem had been solved and the quantity of solids entering the lime treatment unit had been reduced, the data was representative of a properly operating unit.

Table 8 contains monthly average data on the treatment plant influent and effluent BOD, COD, and solids. Analyses of the influent to the lime treatment unit are the same as the biologically treated effluent

TABLE 8

AVERAGE ORGANIC AND SOLIDS ANALYSES OF INFLUENT AND CHEMICALLY TREATED EFFLUENT

MONTH 1969	BOD*		COD*		SS*		VSS*		pH	
	INF.	EFF.	INF.	EFF.	INF.	EFF.	INF.	EFF.	INF.	EFF.
January	827	--	1960	--	162	--	152	--	10.3	--
February	1438	43	2375	105	338	171	200	82	11.2	10.8
March	1458	129	3551	382	450	1141	333	452	9.8	10.4
April	835	55	1545	398	449	621	148	324	9.8	11.0
May	1139	30	2571	104	197	40	195	16	9.8	10.5
June	983	10	2132	74	146	27	76	13	10.3	11.4

*Expressed as mg/l

TABLE 8s

STATISTICAL ANALYSIS OF INFLUENT AND CHEMICALLY TREATED EFFLUENT ORGANIC AND SOLIDS CONCENTRATIONS

		Data Points	Mean	Standard Deviation
BOD*	INF.	57	1327	1261
Daily Figures	EFF.	49	50	50
BOD*	INF.	6	1113	359
Monthly Averages	EFF.	5	53	41
COD*	INF.	57	2419	1409
Daily Figures	EFF.	49	191	169
COD*	INF.	6	2356	624
Monthly Averages	EFF.	5	213	145
SS*	INF.	57	302	346
Daily Figures	EFF.	49	354	738
SS*	INF.	6	290	128
Monthly Averages	EFF.	5	400	429
VSS*	INF.	55	184	155
Daily Figures	EFF.	48	157	289
VSS*	INF.	6	184	78
Monthly Averages	EFF.	5	177	178
pH	INF.	57	10.1	1.2
Daily Figures	EFF.	49	10.8	0.9
pH	INF.	6	10.2	0.5
Monthly Averages	EFF.	5	10.8	0.4

*Expressed as mg/l

found in Table A-4. Figures 6 and 7 show the chemical treatment influent and effluent BOD and COD, respectively. The average BOD in the influent to the lime treatment unit was 30 mg/l for the total season while the average BOD of the effluent was 50 mg/l. There are two reasons for this apparent increase in BOD across the lime unit. The first is that BOD's were analysed on settled samples from the activated sludge clarifier, while BOD's were analysed on the total sample on the effluent of the lime unit. It was necessary to run BOD's on the settled samples from the activated sludge clarifier because solids were purposely wasted to the lime unit for disposal. A more realistic picture of the effectiveness of the lime treatment unit efficiency can be obtained from data collected from June 4 to July 2. During this period, average BOD's in the influent were 7 mg/l and average BOD's of the effluent were 5 mg/l. Examination of the data shows that COD and solids removal were in approximately the same ratio as the BOD removal.

TREATMENT EFFICIENCY OF THE LIME UNIT FOR NUTRIENT REMOVAL

Table A-3 in the Appendix contains monthly averages of the nutrient analyses performed throughout the plant. Table 9 gives the percent removal efficiency in monthly averages of the lime treatment unit for organics and nutrients. Tabulated below are the average influent and effluent nutrient analyses for the complete citrus season and for the period June 4 through June 12.

	Total Citrus Season		June 4 - June 12	
	Influent mg/l	Effluent mg/l	Influent mg/l	Effluent mg/l
Total N	3.80	4.95	2.55	1.88
Ammonia N	0.49	0.69	0.84	0.25
Organic N	3.14	4.28	1.78	1.60
NO_3 + NO_2-N	0.04	0.49	0.03	0.01
NO_2 N	0.01	0.01	0.01	0.00
NO_3 N	0.02	0.03	0.02	0.01
Total P	3.20	2.10	2.33	0.46
Ortho P	1.23	0.67	2.07	0.30
Total P (Filtered)	1.20	0.69	1.26	0.16
Ortho P (Filtered)	0.75	0.25	0.97	0.11

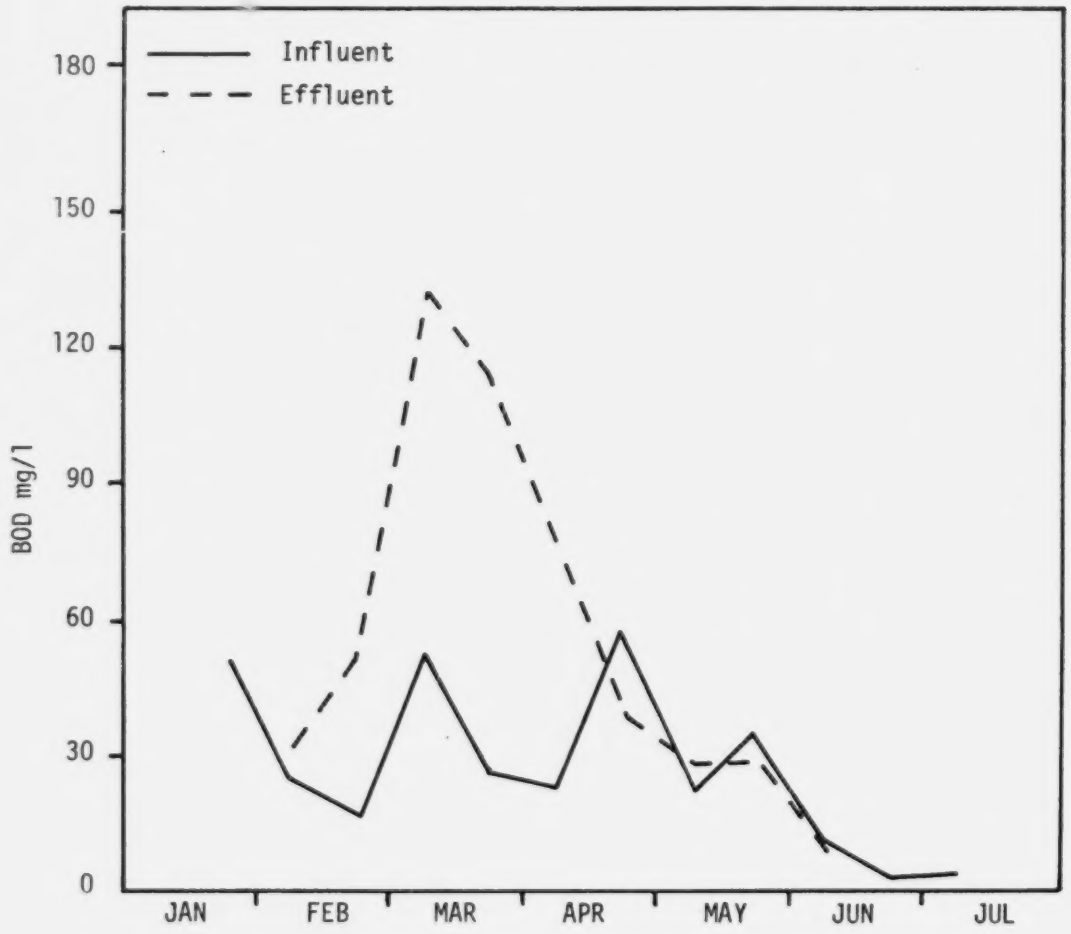


FIGURE 6 - CHEMICALLY TREATED INFLUENT AND EFFLUENT BOD
(SEMIMONTHLY AVERAGES - 1968-69 SEASON)

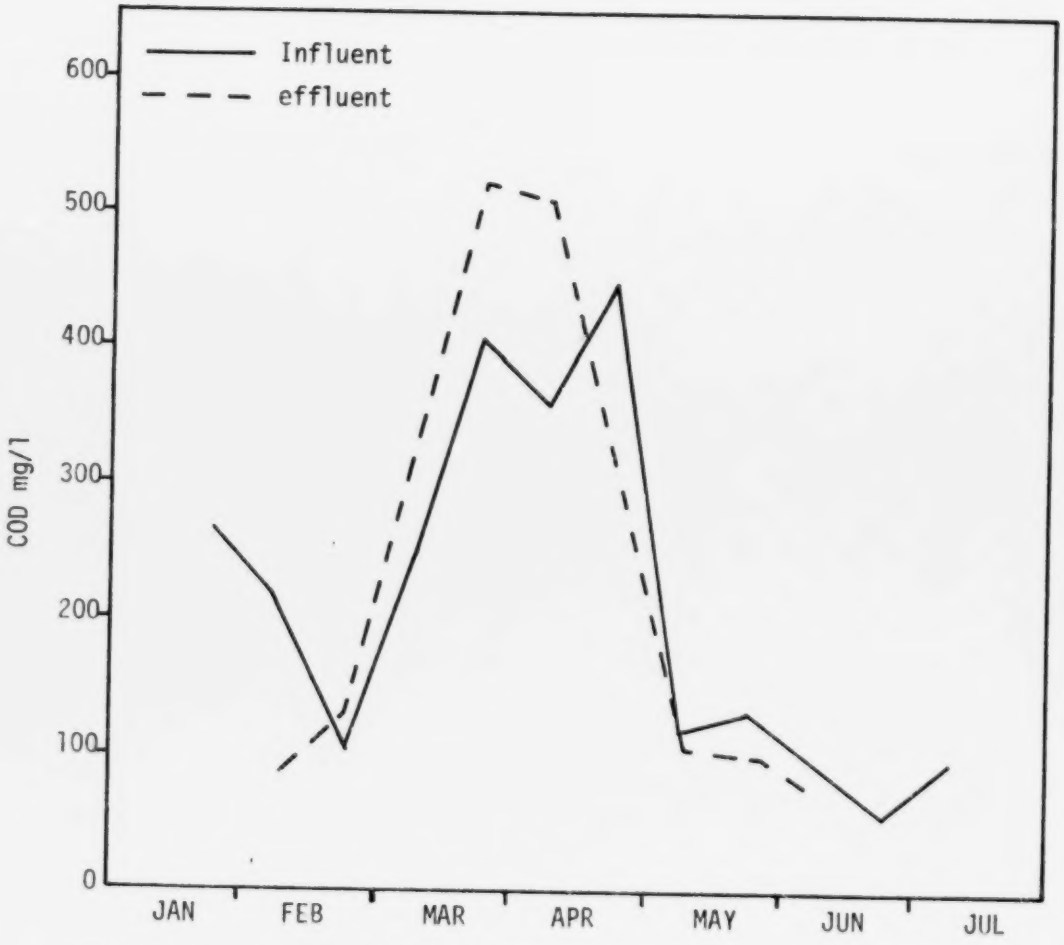


FIGURE 7 - CHEMICALLY TREATED INFLUENT AND EFFLUENT COD
(SEMIMONTHLY AVERAGES - 1968-69 SEASON)

TABLE 9

LIME TREATMENT REMOVAL OF NUTRIENTS AND ORGANICS

Month 1969	BOD		Total Nitrogen		Total Phosphorus		Orthophosphate		pH	Coagulant	
	Effluent mg/l	Removal %	Effluent mg/l	Removal %	Effluent mg/l	Removal %	Effluent mg/l	Removal %		Type	Lime Dosage mg/l
February	43	10	4.21	16	2.51	43	1.04	23	11.6	CaO + Starch	298
March	129	0	6.82	8	5.36	35	1.02	22	10.4	CaO + Alum	314
April	55	37	6.83	3	1.94	22	0.77	8	10.9	CaO Alone	516
May	30	11	4.30	13	0.62	39	0.54	52	10.5	CaO Alone	183
June	10	23	2.55	24	0.53	57	0.31	64	11.4		405

TABLE 9s

STATISTICAL ANALYSIS OF LIME TREATMENT REMOVAL OF NUTRIENTS AND ORGANICS

		Data Points	Mean	Standard Deviation
BOD Daily Figures	Effluent, mg/l	42	58	58
	Removal %	42	12	18
BOD Monthly Averages	Effluent, mg/l	5	53	40
	Removal %	5	16	13
Total Nitrogen Daily Figures	Effluent, mg/l	41	4.87	3.18
	Removal %	41	13	19
Total Nitrogen Monthly Averages	Effluent, mg/l	5	4.94	1.66
	Removal %	5	13	7
Total Phosphorus Daily Figures	Effluent, mg/l	44	2.19	2.89
	Removal %	44	40	28
Total Phosphorus Monthly Averages	Effluent, mg/l	5	2.19	1.76
	Removal %	5	39	11
Orthophosphate Daily Figures	Effluent, mg/l	44	0.70	0.63
	Removal %	44	37	31
Orthophosphate Monthly Averages	Effluent, mg/l	5	0.74	0.28
	Removal %	5	34	21
pH Daily Figures		42	10.9	0.8
pH Monthly Averages		5	11.0	0.5
Lime Dosage, mg/l Daily Figures		41	324	200
Lime Dosage, mg/l Monthly Averages		5	343	112

The effect of foaming and carryover of solids is most pronounced for the nitrogen determinations. The fact that the effluent nitrogen concentrations are higher than the influent concentrations is attributed to the sampling method. All nutrient analyses on the influent to the lime treatment tank were conducted on settled samples. This in effect removed most of the solids associated with foam carryover. Nutrient analyses on the effluent were made on the complete sample which included all solids not effectively removed in the lime treatment unit. Due to the quantity of activated solids going into the lime unit during a considerable portion of the citrus processing season, it is probable that a portion of these solids were placed into fine colloidal form or into solution due to the mechanical interaction of the lime solids.

Over the entire citrus processing season, total phosphorus concentrations in the lime tank influent and effluent averaged 2.98 and 2.19 mg/l, respectively, for a removal efficiency of only 39 percent. During the period June 4 - June 12, influent and effluent total phosphorus concentrations averaged 2.33 and 0.46 mg/l, respectively, for a treatment efficiency of 80 percent. The use of such a short period of time to try to indicate the lime treatment unit efficiency, under optimum conditions, is not desirable. It is questionable whether a lime unit, with the addition of lime at a cost of $40 to $60 per day, is justified from an economic standpoint only to remove 1 to 2 mg/l of phosphorus from a waste treatment plant effluent unless the treated water is to be reused and requires a high water quality.

The lime unit was taken out of operation the last two weeks of June and an attempt was made to use this unit as a waste activated sludge thickener. The lime unit proved too large for continuous sludge thickening because the long detention time allowed the sludge to become anaerobic.

REUSE OF LIME TANK EFFLUENT INPLANT

Effluent from the treatment plant was successfully reused inplant for considerable periods of time. Reuse was limited to use as barometric leg water for two reasons: (1) the high pH from a lime treatment unit will cause deposition of $CaCO_3$ in pipes and on equipment unless the pH is reduced close to the pH_s, (2) extensive piping changes would have to be made to reuse the water as cooling water in the citrus processing plant.

Although there was no question that the lime treated effluent could be reused as barometric leg water and cooling water at Winter Garden Citrus Products Cooperative by adjusting the pH with CO_2 and installing the required piping, it was cheaper and easier at the time to pump well water from the abundant groundwater supply.

CENTRIFUGE OPERATION

Thickening waste sludge was the most disappointing operation in the treatment process. Treatment efficiency of any biological waste treatment system depends largely on the ability to remove excess sludge from the system, in this case for recovery as a cattle feed additive. Thickening of the waste sludge was necessary to prevent overloading of the rotary dryers, and a Bird 24 x 48 inch solid bowl centrifuge was employed for this purpose.

The centrifuge operated unsatisfactorily during the entire citrus season. The main problem was the inability to keep the centrifuge in operation because of shear pin failure. Early in the season, a major mechanical failure occurred in the centrifuge and it had to be rebuilt.

Major factors contributing to the poor performance of the centrifuge were several: (1) the complete treatment plant design was based on parameters developed during a six weeks laboratory study; (2) there were no firm parameters for centrifuge design; and (3) the waste sludge composition entering the centrifuge was of considerable variability.

Waste sludge from the treatment plant was pumped to a holding tank in the citrus processing plant before it was centrifuged. The variation of the solids from this surge and thickening tank was considerable. Lime solids tended to separate from the activated sludge solids and settle to the bottom. After a long period of time when no solids had been withdrawn, the solids concentration in the bottom of the unit increased to as high as 10 to 12 percent (see Table A-6 of the Appendix). A sudden slug of this material fed into the centrifuge invariably sheared a pin. Even after a fairly consistent solids concentration was fed to the centrifuge, it was difficult to maintain continuous operation. When the centrifuge was operating, it tended to classify the solids, removing the heavier lime solids and passing the activated sludge solids back to the plant.

The manufacturer spent considerable time trying to adjust the machine in order for it to perform properly. The R.P.M. was reduced toward the latter part of the season and this seemed to be the answer for continuous operation.

The inability of the centrifuge to operate properly meant that solids could not be wasted as desired. When the centrifuge was not operating, thickened solids from the bottom of the surge tank were placed directly on the citrus peel for drying. The dryers, however, were already

heavily loaded and all of the waste solids could not be recovered as a cattle feed additive. The resulting solids build up in the waste treatment plant compounded the foaming problem.

In summary it can be said that a solid bowl centrifuge should not be considered for sludge dewatering unless extensive pilot plant testing has proved its efficiency.

SUMMARY OF 1968-69 CITRUS PROCESSING SEASON

The initial start-up of the activated sludge system proved to be no problem as the aeration tanks were initially filled with well water and a biological floc quickly formed after introduction of the wastewater. It was found that seeding would not be necessary. The wastewater pH proved to be higher than expected; therefore, pH control was seldom necessary. The control of the addition of nutrients to the nutrient deficient wastewater was found to be easily controlled by monitoring the soluble nutrients in the activated sludge system. This method of nutrient control proved to be highly effective and resulted in a minimum concentration of nutrients in the effluent of the activated sludge system.

The two major problems associated with the activated sludge process were foaming and high MLSS. The high MLSS (3,000 to 7,000 mg/l) was caused by the inability to waste activated sludge as required. Foaming was caused by slugs of peel press liquor and centrate water from the orange oil recovery system. Foaming resulted in low D.O. concentrations in the activated sludge process and carry-over of solids into the lime treatment unit. Foaming was experienced frequently throughout the season and only came under control when the centrate water from the orange oil recovery system was diverted to the molasses evaporators and discharge of peel press liquor was reduced. Even with the problems associated with the activated sludge process, the average treatment efficiency approached 99 percent.

The lime treatment proved unable to handle all waste activated sludge as originally designed. It was found that activated sludge could not be wasted over the weirs of the clarifier into the lime unit. It was found that excess solids carryover caused by foaming in the activated sludge system would completely disrupt the lime treatment unit. Only when the effluent from the activated sludge system had very low suspended solids did the lime unit perform satisfactorily. Because it was found that the effluent nutrients from the activated sludge process could be effectively controlled by controlling the influent nutrient addition, the lime treatment unit proved to be unnecessary.

Treatment plant effluent was reused inplant for both cooling water and barometric leg water. The pH of the lime unit (approx. 10.5) proved to be too high to be used on a continuous basis because of deposition of $CaCO_3$. Recarbonation to lower the pH to a more acceptable level would have allowed continuous use of the effluent as either cooling or barometric leg water.

Waste activated sludge and lime sludge could not be effectively thickened or dewatered by the solid bowl centrifuge. Although numerous attempts were made to obtain satisfactory operation from the centrifuge, the machine proved to be totally inadequate. This meant that waste sludge after gravity thickening had to be discharged directly to the rotary kiln dryers. Because of the limit in the quantity of water the dryers could evaporate, sludge could not be wasted as desired. This meant carrying exceedingly high MLSS in the aeration system.

Waste activated and lime sludge proved to be easily used as a cattle feed additive with the exception of the high moisture content problem. Thousands of tons of dried citrus peel containing small quantities of waste activated and lime sludge were sold and consumed by cattle with no ill effect.

SECTION V

1969-70 CITRUS PROCESSING SEASON

MODIFICATIONS TO WASTE TREATMENT SYSTEM PRIOR TO 1969-70 SEASON

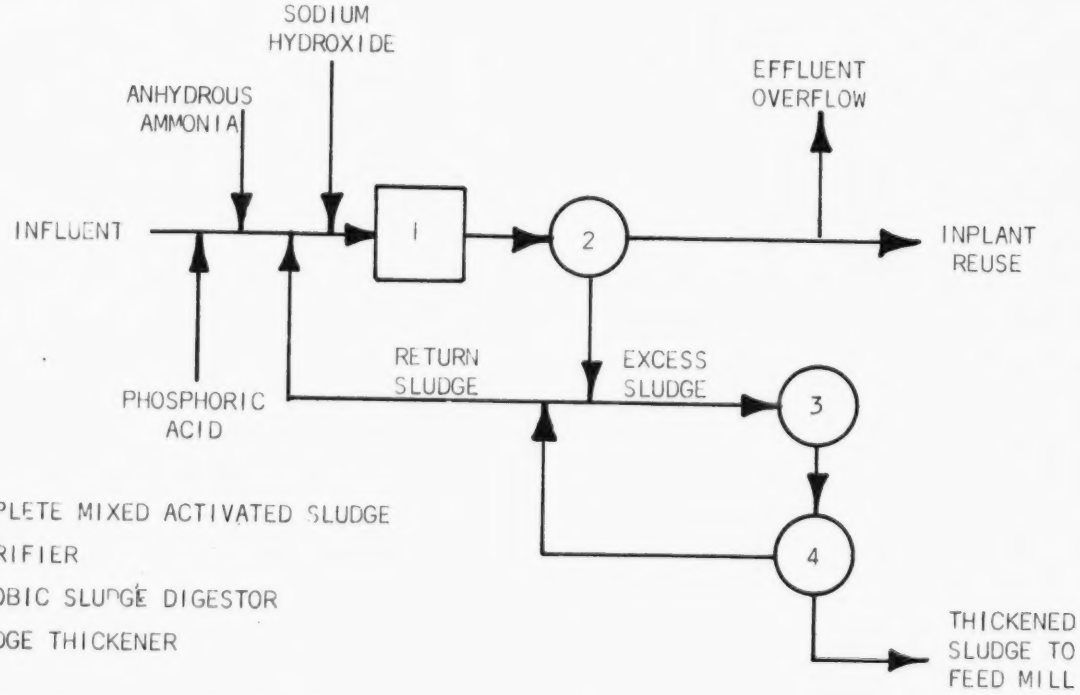
During the 1968-69 processing season, it became obvious that the lime treatment was not necessary for effluent nutrient control. Reuse of the treatment plant effluent did not require the low suspended solids the lime unit was capable of producing. Therefore, with the approval of the Environmental Protection Agency, lime treatment was discontinued and the lime unit converted to a sludge holding tank and aerobic digester. Figure 8 shows a schematic diagram, and Figures C-1 through C-4 in the Appendix show photographs, of the modified waste treatment system as operated during the 1969-70 season.

The only modifications to the entire treatment process was conversion of the lime unit to an aerobic digester. This was done quite inexpensively by installing two 25 h.p. injector aerators which had been junked at another waste treatment plant. These aerators were easily installed after removing the outside weir from the lime treatment unit and installing piping which allowed the discharge of waste activated sludge into the unit and removal of supernatant back into the aeration basins. Figure C-2 shows the modified lime treatment unit.

WASTEWATER FLOW AND FRUIT PROCESSED

A record of the wastewater flow and quantity of fruit processed was kept each day of the season with the exception of the time from November 11, 1969, to December 18, 1969. During this period, the Parshall flume was being bypassed while piping modifications were being made. Wastewater flow ranged from 0.0 MGD to 1.9 MGD with an average daily flow of 1.1 MGD.

The number of boxes of fruit processed each day varied widely during the season. This was due to weather conditions, the availability of fruit, etc. The number of boxes of fruit processed varied from 0.0 to 67,800 per day. The average was 34,000 boxes each day that fruit was processed. Based upon average wastewater flow and boxes of fruit processed, the average gallons of wastewater per box of fruit was 31 gallons and the average pounds of BOD per box of fruit was 0.40. Table 10 is a tabulation of the monthly average wastewater flow and boxes of fruit processed per day. A complete tabulation is shown in Table B-1 in the Appendix.



1. COMPLETE MIXED ACTIVATED SLUDGE
2. CLARIFIER
3. AEROBIC SLUDGE DIGESTOR
4. SLUDGE THICKENER

FIGURE 8 MODIFIED WASTE TREATMENT SYSTEM

TABLE 10

AVERAGE WASTEWATER FLOW AND FRUIT PROCESSED

Month 1969-70	Flow Rate MGD	Oranges 1000 Boxes*	Grapefruit 1000 Boxes*
November	---	9.1	0.0
December	0.8	22.5	
January	1.5	47.9	0.0
February	1.2	45.6	0.0
March	0.7	12.0	5.5
April	0.8	27.7	0.1
May	1.3	51.7	0.0
June	1.3	45.9	0.0

*One box is 90 pounds of fruit.

TABLE 10s

STATISTICAL ANALYSIS OF WASTEWATER FLOW AND FRUIT PROCESSED

	Data Points	Mean	Standard Deviation
Flow Rate, MGD			
Daily Figures	151	1.1	0.5
Monthly Averages	7	1.1	0.3
Fruit Processed, 1000 Boxes			
Daily Figures	228	34.5	22.7
Monthly Averages	8	33.5	15.2

Number of days of zero flow = 0
Number of days for which flow data is unavailable = 38
Number of days of no fruit production = 40

NUTRIENT ADDITION AND pH CONTROL

Nutrients were added to the influent wastewater in the form of ammonia and phosphoric acid as had been done the previous year. Modifications to the activated sludge system made between the 1968-69 season and the 1969-70 season consisted only of the conversion of the lime tank to an aerobic digester; therefore the operation was essentially the same. Test kits were again used to measure the ammonia nitrogen and orthophosphate in the aeration tanks in order to control the additions of nutrients to the influent wastewater. Table B-2 in the Appendix shows the average pounds per day of anhydrous ammonia as N and average pounds per day of phosphoric acid as P added to the influent wastewater each month. Addition of nitrogen and phosphorus varied widely throughout the citrus season depending upon the loading rate on the activated sludge process and the ability of the plant operators to measure the effluent nutrient concentration. Figures 9 through 13 show the influent and effluent nutrient concentrations. The wastewater required little pH control because of the relatively high pH of the wastewater. Only when slugs of peel press liquor entered the system was it necessary to add sodium hydroxide.

ACTIVATED SLUDGE PROCESS OPERATIONAL PROBLEMS

Several operational problems were encountered during the 1969-70 season. Foaming in the aeration tanks was one of the major problems. Foaming occurred sporadically during most of the season and usually occurred when quantities of peel press liquor or water from the centrifuges of the oil recovery system entered the waste treatment plant. Foaming resulted in a decrease in the aeration transfer capacity of the surface mechanical aerators. Foaming also caused suspended solids to be discharged over the weirs of the clarifier because of the lack of a surface skimmer. These solids decreased the overall treatment efficiency of the system causing higher effluent BOD concentrations than were desirable.

Mechanical problems with the surface aerators caused low D.O. concentrations for days at a time. The main problem was the failure of aerator gear boxes which necessitated the aerators being taken out of service for repair. Aeration capacity was borderline even with all aerators in service. Therefore, when a mechanical failure occurred, the D.O. in the aeration tanks decreased to less than 1.0 mg/l. This caused higher effluent BOD's and an overall decrease in treatment efficiency.

Again, inability to waste sludge as required was a major problem. The unsatisfactory operation of the centrifuge made it necessary to discharge waste activated sludge directly to the rotary kiln dryers without further thickening. Since the rotary dryers could

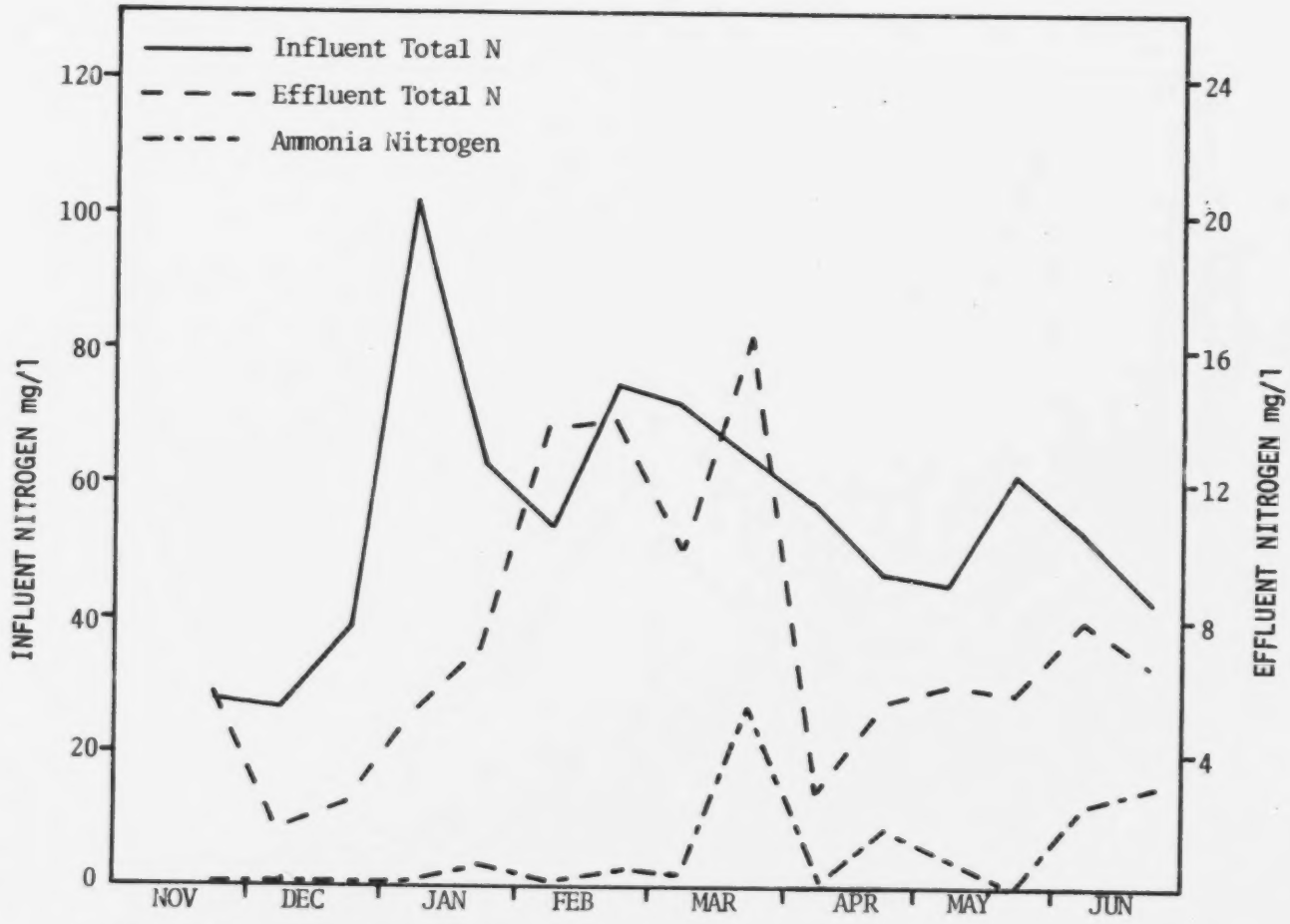


FIGURE 9 - INFLUENT AND EFFLUENT TOTAL NITROGEN AND EFFLUENT AMMONIA NITROGEN (SEMIMONTHLY AVERAGES - 1969-70 SEASON)

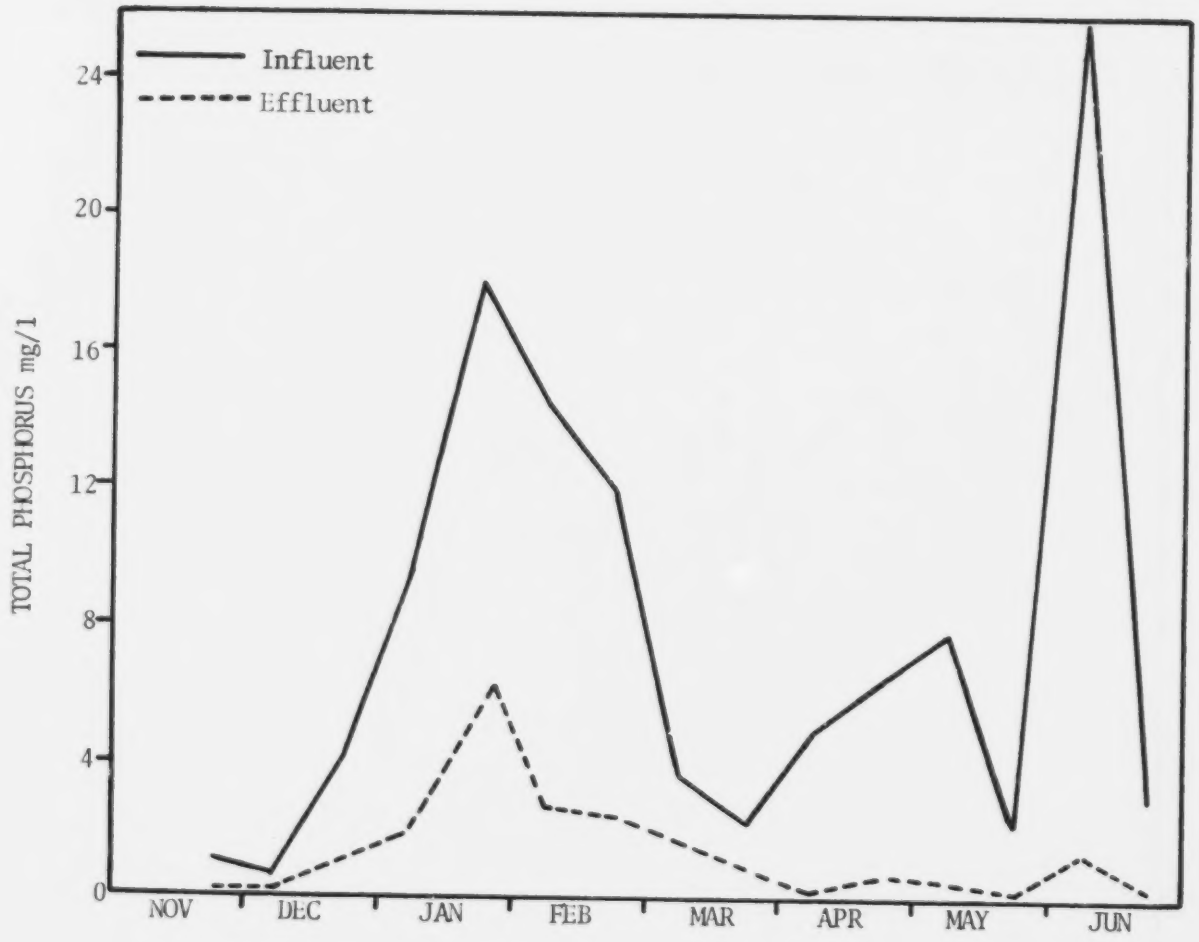


FIGURE 10 - INFLUENT AND EFFLUENT TOTAL PHOSPHORUS
(SEMIMONTHLY AVERAGES - 1969-70 SEASON)

FIGURE 11 - INFLUENT AND EFFLUENT ORTHOPHOSPHATE
(SEMIMONTHLY AVERAGES - 1969-70 SEASON)

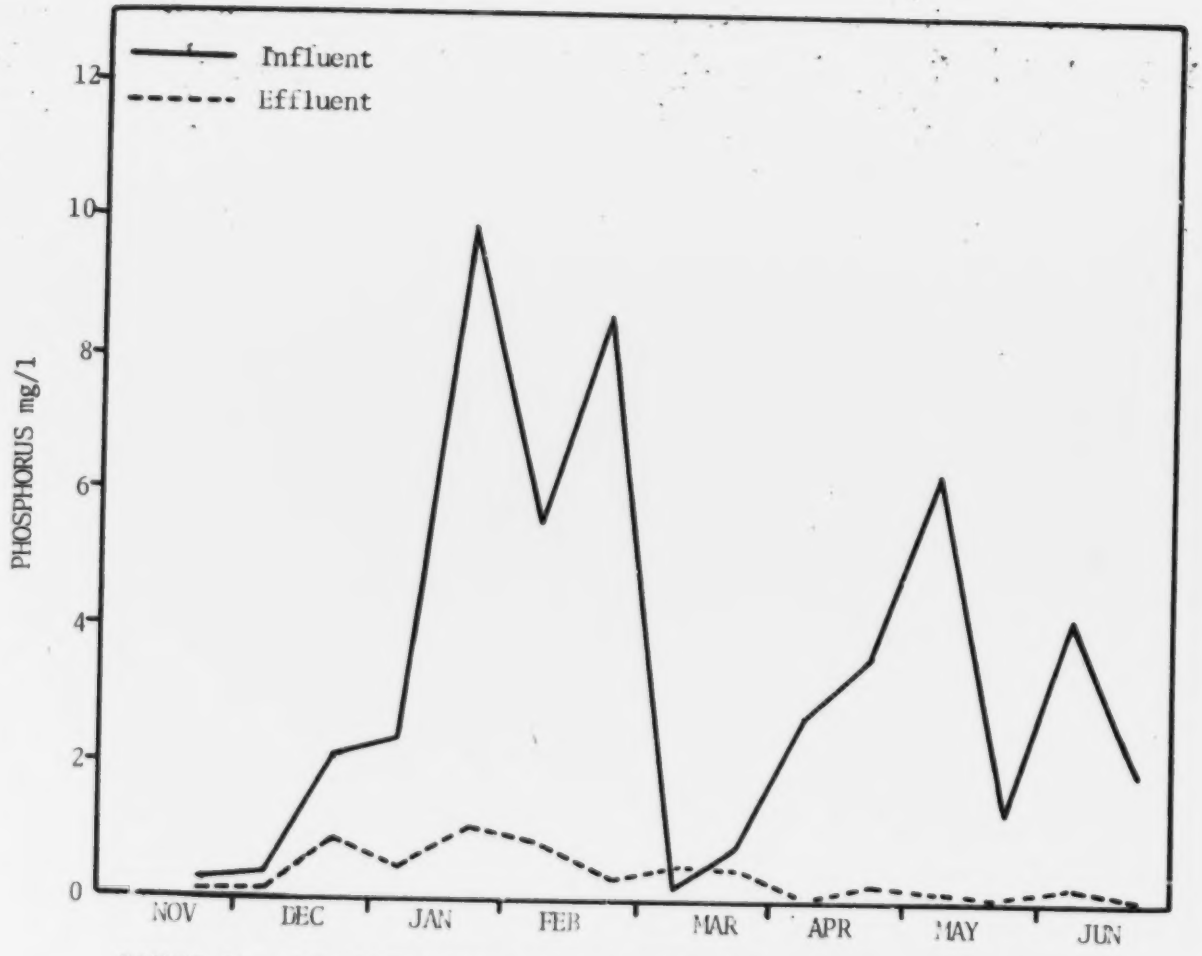


FIGURE 12 - FILTERED INFLUENT AND FILTERED EFFLUENT TOTAL PHOSPHORUS
(SEMIMONTHLY AVERAGES - 1969-70 SEASON)

FIGURE 13 - FILTERED INFLUENT AND FILTERED EFFLUENT ORTHOPHOSPHATE
(SEMIMONTHLY AVERAGES - 1969-70 SEASON)

only handle a limited amount of the waste sludge, sludge disposal by tank truck to citrus groves was practiced in an attempt to maintain a desirable MLSS concentration. The MLSS approached 7000 mg/l which caused increased oxygen uptake rates and low D.O. concentrations in the aeration basins.

AERATION TANK ANALYSES

Every two hours, samples were collected from both aeration tanks to determine D.O., pH, MLSS, and SVI. Table 11 contains monthly averages of these results. Dissolved oxygen concentrations varied widely during the season. D.O. concentrations below 1.0 mg/l occurred when foaming and heavy organic loadings of the system existed or when an aerator was not in operation because of mechanical failure.

The pH of the mixed liquor varied from 5.7 to 8.1. The pH of 5.7 was measured immediately after a large volume of peel press liquor was discharged to the treatment system. Although the pH of the influent waste varied widely, the pH of the aeration basins usually ranged from 7.1 to 7.8.

The MLSS concentration of the aeration basin was always high. MLSS values approached 7000 mg/l on several occasions and normally were around 4500 mg/l.

The sludge volume index (SVI), which is a measure of the settling rate of the sludge, varied from 73 to 440. Most SVI values were between 150 and 250 which meant the sludge settled slowly in the sludge clarifier.

ACTIVATED SLUDGE PROCESS TREATMENT EFFICIENCY AND LOADING RATES

Table B-3 in the Appendix gives the monthly average influent and effluent BOD, COD, and solids analyses. Figures 14 and 15 show the influent and effluent BOD and COD, respectively. Maximum and minimum BOD concentrations in the influent were 4250 mg/l and 155 mg/l. Maximum and minimum BOD's in the effluent were 90 mg/l and 1.0 mg/l. The average influent BOD was 1300 mg/l and the average effluent BOD 20 mg/l. This is an average BOD reduction of 98.5 percent for the 1969-70 season.

Although this is excellent treatment efficiency, problems with foaming and excess solids caused lower treatment efficiency than would have been attainable if closer control could have been maintained on the discharge of peel press liquor, orange oil, and other high BOD wastes, and if control of the solids in the aeration basins could have been maintained. Discharge of peel press liquor and orange oil were caused by inplant evaporation deficiency or mechanical failure.

TABLE 11

AVERAGE AERATION TANK ANALYSES

Month 1969-70	North Aeration Tank				South Aeration Tank			
	MLSS mg/l	SVI	D.O. mg/l	pH	MLSS mg/l	SVI	D.O. mg/l	pH
November	3001	324	4.9	7.5	--	--	--	--
December	4932	199	4.4	7.6	3275	301	4.4	7.3
January	5042	193	2.0	7.2	4878	195	2.1	7.4
February	4803	171	1.6	7.8	4835	176	2.0	7.6
March	3939	240	4.2	7.5	3855	241	4.6	7.7
April	3595	280	3.1	7.3	3559	285	3.4	7.5
May	4391	223	0.5	7.4	4379	224	0.8	7.4
June	4358	227	1.0	7.7	4365	228	1.4	7.7

TABLE 11s

STATISTICAL ANALYSIS OF AERATION TANK ANALYSES

		North Aeration Tank			South Aeration Tank		
		Data Points	Mean	Standard Deviation	Data Points	Mean	Standard Deviation
MLSS mg/l	Daily Figures	219	4343	924	177	4293	863
	Monthly Averages	8	4258	663	7	4164	573
SVI	Daily Figures	219	226	59	177	226	54
	Monthly Averages	8	232	46	7	236	42
D.O. mg/l	Daily Figures	220	2.7	2.5	177	2.7	4.7
	Monthly Averages	8	2.7	1.6	7	2.7	1.4
pH	Daily Figures	219	7.5	0.4	167	7.5	0.3
	Monthly Averages	8	7.5	0.2	7	7.5	0.1

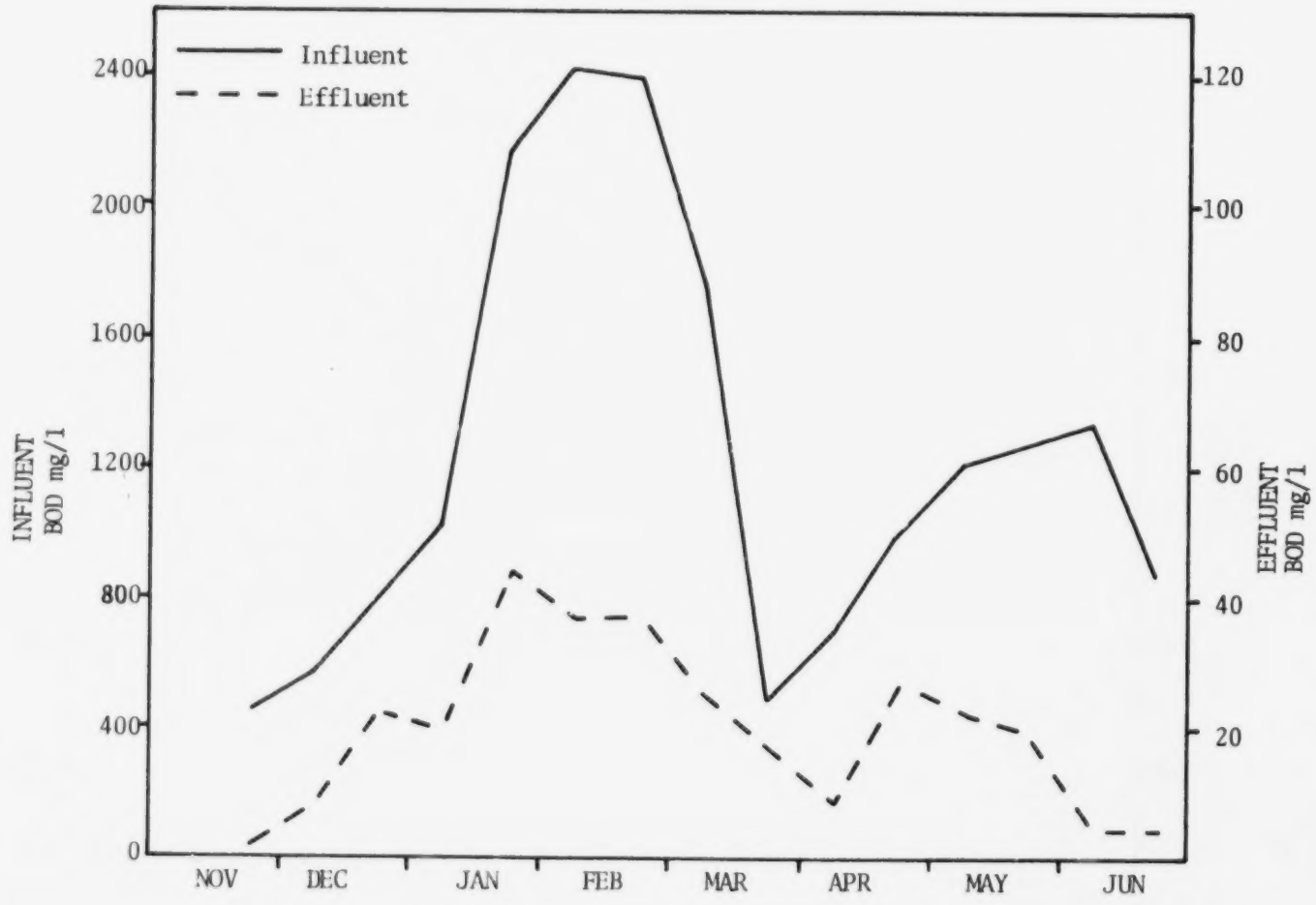


FIGURE 14 - INFLUENT AND EFFLUENT BOD
(SEMIMONTHLY AVERAGES - 1969-70 SEASON)

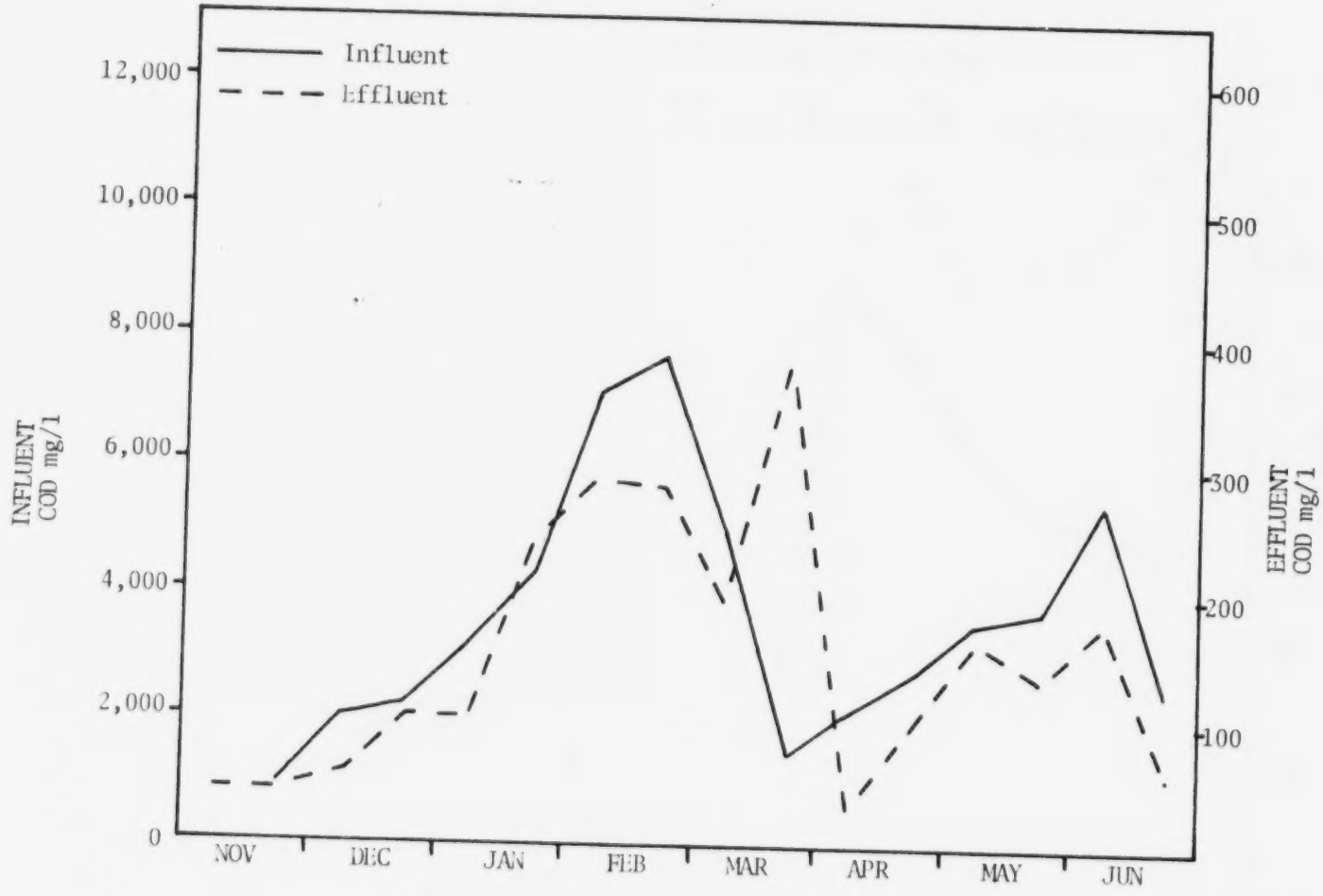


FIGURE 15 - INFLUENT AND EFFLUENT COD
(SEMIMONTHLY AVERAGES - 1969-70 SEASON)

Figure 16 shows the semimonthly average loading rate in pounds BOD per pound MLSS. Loading rates varied from a minimum of 0.01 to a maximum of 0.58 pounds BOD/lb MLSS. Average loading rates during February 1970 were greater than 0.2 pounds BOD/lb MLSS, which is a loading comparable to the conventional activated sludge process. Table 12 shows monthly averages of influent BOD, flow rate, mixed liquor suspended solids, and loading rate for the complete citrus season. Daily figures are shown in Table B-4 in the Appendix. Loading rates varied considerably from day to day depending upon amount of fruit processed and other inplant operations. It was not unusual to go several days without any wastewater flow to the treatment system because of the lack of fruit. This had no detrimental effect on the system as it was able to take wide variations in loading without a decrease in treatment efficiency.

WASTE ACTIVATED SLUDGE

Waste activated sludge was discharged directly to the aerobic digester, which had formerly been the lime treatment unit, where it was aerated almost continuously. Only while supernatant was being pumped back to the aeration tanks were the aerators cut off.

Detention time in the digester was approximately 2 days, which was not enough time to aerobically digest the waste sludge. Digestion was not necessary, however, since the sludge was to be recovered as a cattle feed additive. The digester functioned more as a surge and thickening tank than a digester.

Table B-5 in the Appendix shows the monthly average daily volume of sludge wasted from the digester to the citrus plant. This table also shows the influent and effluent solids. Average influent solids were 0.93 percent and average effluent solids were 2.27 percent. If the digester was converted to a continuous sludge thickener, a sludge concentration of approximately 3.5 percent could be realized. When this was attempted, odor problems resulted because of the long detention time. Calculations indicate approximately 0.5 to 0.6 pounds of waste sludge were produced per pound of BOD treated.

CENTRIFUGE OPERATION

The 24" x 48" Bird solid bowl centrifuge was operated intermittently during the citrus season. Numerous experiments were conducted in an attempt to obtain the best efficiency from the machine. The influent feed rate was varied, the pool depth, type of coagulant, dispersion water, and even the rpm were varied with the centrifuge still giving unsatisfactory results.

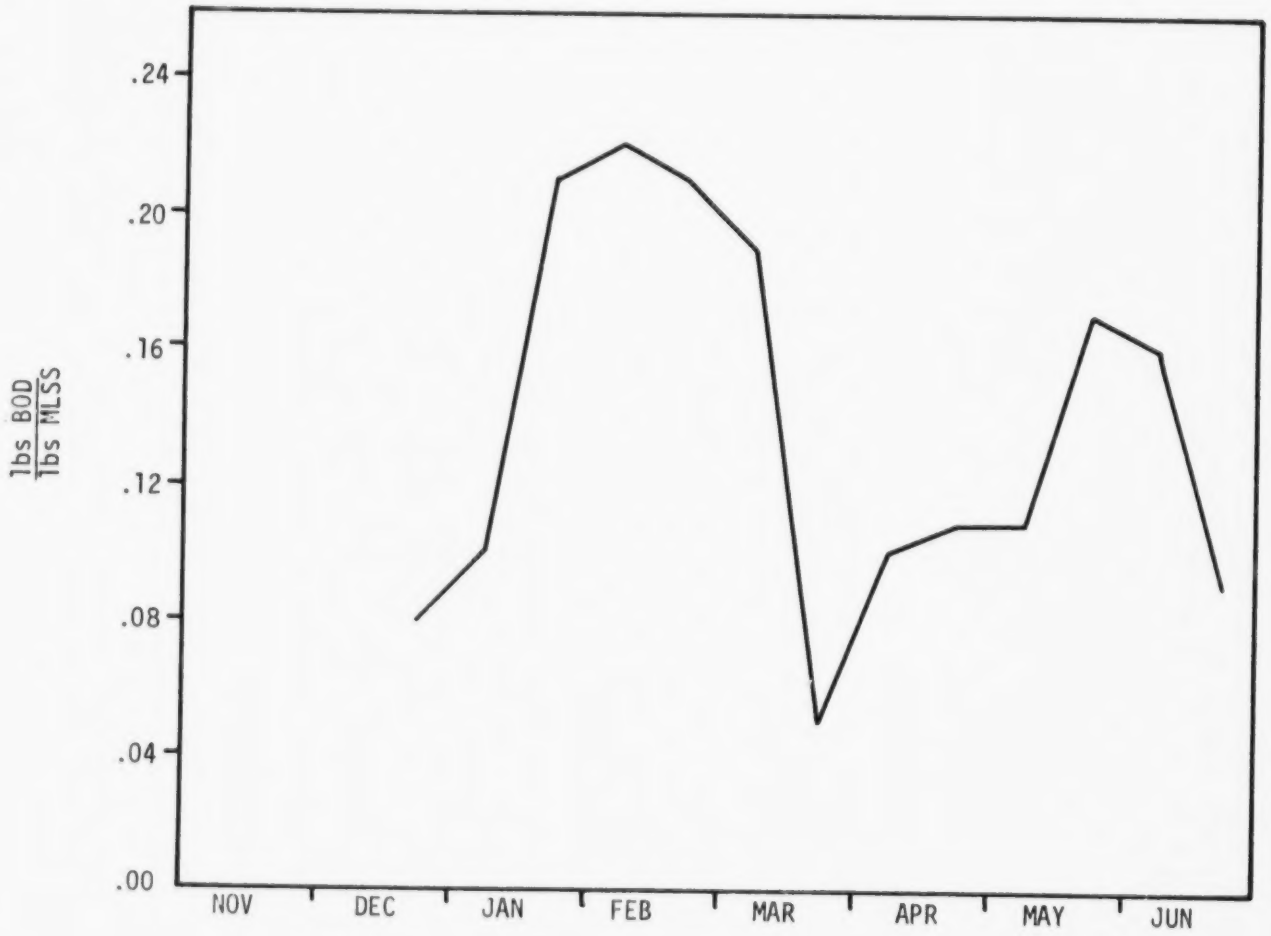


FIGURE 16- ACTIVATED SLUDGE PROCESS LOADING RATES
SEMIMONTHLY AVERAGES - 1969-70 SEASON

TABLE 12

AVERAGE ACTIVATED SLUDGE PROCESS LOADING RATES

Month 1969-70	BOD mg/l	Flow Rate MGD	Average MLSS mg/l	lbs BOD/ lb MLSS
December	668	1.2	4237	.07
January	1715	1.5	5319	.17
February	2409	1.2	4824	.21
March	1334	1.2	4119	.14
April	925	1.4	4073	.10
May	1230	1.4	4346	.12
June	1103	1.4	4344	.12

TABLE 12s

STATISTICAL ANALYSIS OF ACTIVATED SLUDGE LOADING RATES

	Data Points	Mean	Standard Deviation
BOD, mg/l	7	1341	531
Flow Rate, MGD	7	1.3	0.1
Average MLSS, mg/l	7	4466	416
lbs BOD/lb MLSS	7	0.13	0.04

Table B-6 in the Appendix shows the average results of analyses run on samples from the operation of the centrifuge under numerous conditions. A review of this data shows that seldom did the cake from the centrifuge exceed 7 percent and the recovery was very low. Most of the time, waste sludge was placed directly on the peel without thickening for recovery as a cattle feed additive. When the dryers became overloaded, sludge was hauled by tank truck to citrus groves for disposal.

WASTEWATER REUSE

Effluent from the treatment plant was used on a continuous basis for barometric leg water in the molasses evaporators. No problems were encountered even during periods of high activated sludge concentrations in the effluent.

Effluent was also used for cooling of refrigeration equipment on a trial basis. No problems were encountered; however, effluent was not used for this purpose on a continuous basis because the total flow could more easily be used for barometric leg water. Wastewater reuse was considered in several other processes; however, it was rejected due to potential contamination of the food product.

The reuse of the treatment plant effluent decreased the pumping of well water by an amount approximately equal to the plant's discharge, 1.0 to 1.5 MGD. This represents a reduction in the fresh water usage of approximately 20 percent and is a significant step toward total water recycling.

SUMMARY OF 1969-70 CITRUS PROCESSING SEASON

The 1969-70 season was not greatly different from the previous season with the exception that the lime treatment unit had been converted to an aerobic digester and sludge thickener. The construction of the aeration tanks did not allow them to be dewatered; therefore, they contained activated sludge which was aerated throughout the off-season. The system was placed into operation by discharging wastewater into the system and excellent treatment was immediately realized.

The soluble nutrient concentrations in the aeration basins were controlled as they had been the previous year by manually adjusting the addition of phosphoric acid and anhydrous ammonia to the influent.

The pH had to be controlled only when a slug of peel press liquor lowered the pH of the aeration basins. Control was accomplished by the addition of sodium hydroxide.

Although foaming was still a major problem throughout the 1969-70 season, it was not as severe as it had been during the previous season. Inplant modifications had reduced the discharges of peel press liquor and water from the orange oil recovery system.

Inability to waste solids as desired caused high MLSS concentrations in the aeration tanks. These high concentrations combined with mechanical problems with the surface aerators to lower D.O. concentrations below the minimum desired.

In spite of all the problems causing reductions in efficiency of the activated sludge system, the system averaged a 98.5 percent BOD removal during the season.

Waste activated sludge was discharged to the aerobic digester where it was aerated and thickened before being discharged to a holding tank. Sludge was pumped from the holding tank either through the centrifuge to the rotary kiln dryers or directly to the dryers. Since the centrifuge proved itself to be unsatisfactory for dewatering waste activated sludge alone, most of the time the sludge was pumped directly to the dryers. When the dryers became overloaded, excess sludge was hauled away by tank truck for land disposal on citrus groves.

Treatment plant effluent was reused on a continuous basis as barometric leg water. Tests showed that it could also be used as cooling water. Reuse of the effluent as barometric leg water was not a closed system as the barometric waste was discharged to Lake Apopka; however, reuse of the effluent did reduce plant water usage and total wastewater disposal by some 1.5 MGD.

SECTION VI

KINETICS OF SUBSTRATE UTILIZATION

Eckenfe'der[5] has used the Michaelis-Menton relationship to define microbial growth rate and substrate removal in a completely mixed activated sludge system and has developed a simplified equation describing substrate removal:

$$K_a S = \frac{Sr}{X_v t}$$

where

K_a = BOD rate constant

S = effluent BOD

Sr = BOD removed

X_v = average mixed liquor suspended solids

t = detention time

Figure 17 shows plots of BOD removal versus effluent BOD. The slopes of the first order curves passing through (0,0) are equal to the BOD rate constant for the given temperatures.

Figure 18 is a semi-logarithmic plot of the BOD rate constant, K_a, versus temperature. The equation of the straight line is the BOD rate constant temperature correction.

$$K_t = 0.0072 \times 1.278^{(t-20)}$$

where

K_t = BOD rate constant at temperature t (°C)

t = temperature (°C)

It must be noted that the narrow range of aeration basin temperatures did not allow verification of the temperature correction equation over a wide range of temperatures. It must also be noted that soluble effluent BOD and volatile MLSS would have given a more accurate representation of substrate utilization, but these data were unavailable.

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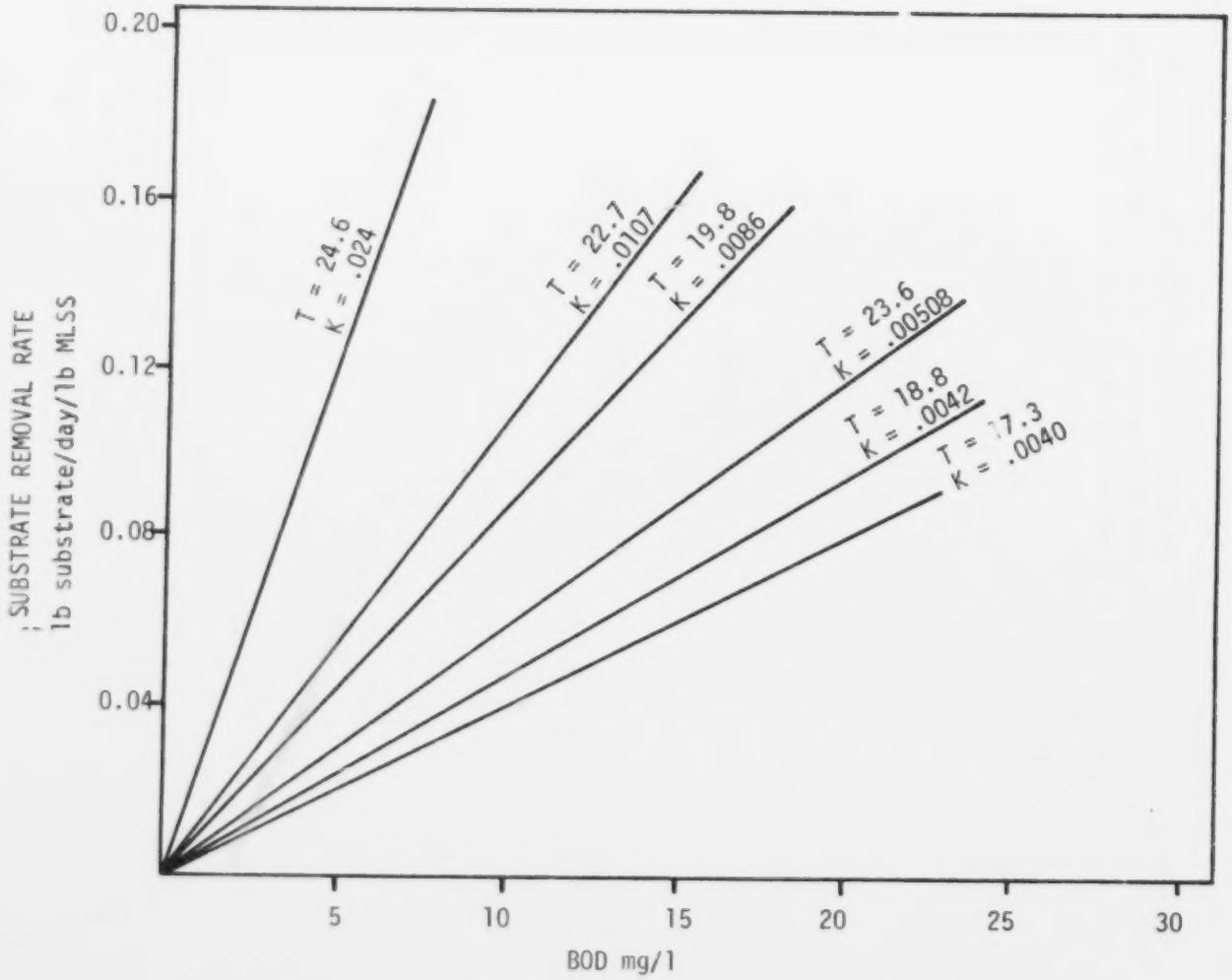

FIGURE 17 - SUBSTRATE REMOVAL VERSUS EFFLUENT BOD

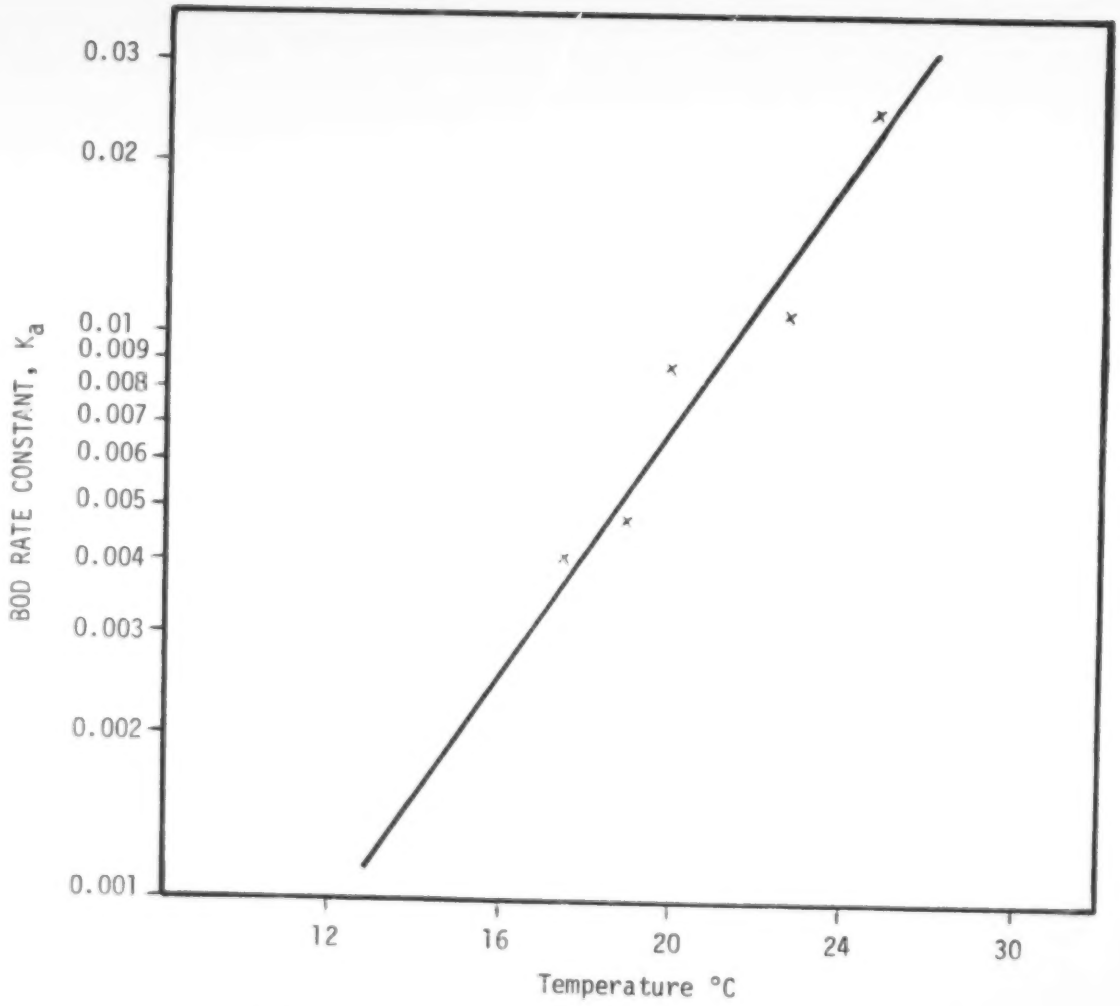

FIGURE 18 - SUBSTRATE REMOVAL RATE VERSUS TEMPERATURE

SECTION VII

WASTE TREATMENT SYSTEM CONSTRUCTION COST AND TREATMENT COST

Waste Treatment System Construction Cost

Winter Garden Citrus Products Cooperative served as their own general contractor with major portions of the construction subcontracted to a private contractor. Since the grant only covered partial funding of the construction of the lime treatment, water re-use, and centrifuge systems a detailed cost breakdown of the total plant is not available. However a general cost breakdown for the treatment plant is shown in Table 13. A list of manufacturers of the major equipment is shown in Table 14.

Several items should be noted in the cost breakdown of the treatment process. The system was designed to handle approximately 33,000 lbs of BOD per day at a cost of only $550,000, and this included approximately $100,000 for tertiary treatment by lime and $30,000 for water reuse facilities. Subtracting the cost of lime treatment and water reuse and adding the cost of two aerators which would be required to handle the design load, the cost for BOD removal alone would have been approximately $450,000.

There are two major reasons for the low cost of the activated sludge system: (1) low cost of aeration tanks, and (2) use of existing equipment for sludge handling. Every conceivable type of construction was considered to provide the volume required for the aeration tanks. Cost estimations showed that simple circular concrete 144-foot diameter tanks would provide the required aeration volume. The specially designed concrete tanks were actually cheaper than steel, prestressed concrete, or lined earthen lagoons.

The walls of the concrete tanks are 1.0 ft thick and 15.67 ft high. The wall sits on a 1.0 ft thick by 3.17 ft slab. The walls did not require circular forms as standard 4 ft X 8 ft plywood was used. This saved considerable money when compared to circular forms. The tank bottom was not a structural bottom but simply a 4.0 inch thick concrete slab. The only disadvantage is that the tanks cannot be completely dewatered when the water table is high.

In domestic waste treatment plants the cost of proper sludge handling facilities may cost as much as 50 percent of the total construction cost. Winter Garden Citrus was in an unusual position in that the waste sludge from the treatment plant could be recovered as a cattle feed additive. This eliminated the need for sludge digestion and disposal facilities which would have added greatly to the capital cost.

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TABLE 13

CONSTRUCTION COST BREAKDOWN

Raw Waste Pumping Structure		$ 15,000
Raw Waste Pumps (3)		5,000
Aeration Tank Structures		90,000
Mechanical Surface Aerators (6)		80,000
Activated Sludge Clarifier Structure		35,000
Activated Sludge Clarifier - Mechanical		10,000
Activated Sludge Return Pumps (3)		5,000
Lime Treatment Structure		45,000
Lime Treatment - Mechanical		35,000
Lime Storage Silo		6,000
Lime and Waste Activated Sludge Transfer Pumps (2)		7,000
Laboratory and Control Building		10,000
Reuse Water Pumping Structure		15,000
Reuse Water Pumps (3)		5,000
Centrifuge		30,000
Chemical Tanks		6,000
Piping		75,000
Electrical		15,000
Controls and Miscellaneous		10,000
Land		21,000
Engineering Services		30,000
	TOTAL	$ 550,000

TABLE 14

MANUFACTURERS OF MAJOR EQUIPMENT

Original Construction For 1968-69 Season

Raw Waste Pumps - 3	Gorman Rupp
Motor Drives - 3	U.S. Electric Motors
Pump Controls - 1	Healy Ruff
Ammonia Feeder - 1	Wallace & Tiernan
Phosphoric Acid Feed Pump - 1	Wallace & Tiernan
Surface Aerators - 6	Permutit
Sludge Collector - 1	Link Belt
Sludge Return Pumps - 3	Cornell Pumps
Lime Reactor	Grave Water Conditioning Co.
Lime Silo - 1	Florida Metalcraft
Lime Slurry Equipment - 1	Wallace & Tiernan
Lime Feed Pumps - 2	Moyno
Lime & Activated Sludge Pumps - 2	Moyno
Effluent Meter and Recorder	Chronoflo
Water Reuse Pumps - 3	Worthington
Pump Controls - 1	Healy Ruff
Centrifuge, 24" x 48" Solid Bowl	Bird Centrifuge

The use of the complete mixed activated sludge process, simple construction techniques, floating surface mechanical aerators, and recovery of waste activated sludge as a cattle feed additive can substantially reduce capital construction cost when compared with cost of other treatment processes.

Treatment Cost

A comparison of the cost of BOD removal for the Winter Garden Citrus treatment plant with other treatment plants is difficult to make because the plant is only operated a few months each year. To correctly compare treatment costs, systems should be operated on a full load basis 365 days a year. It is not possible to compare a plant which operates 150 days a year with a plant which operates 365 days a year. Winter Garden Citrus is a good example of an industrial waste treatment plant which operates only a few months each year and only a few weeks at full capacity. Yet, the waste treatment plant must be designed to handle the peak load.

The capabilities of the waste treatment plant as designed were:

Hydraulic loading	-	2.0 MGD
BOD	-	2,000 mg/l
BOD	-	33,300 lbs/Day

Table 15 shows the operation and maintenance cost for the 1968-69 season and the 1969-70 season. Assuming the $550,000 capital cost is amortized at 8 percent over 20 years, the annual investment retirement cost would be $56,000. Table 16 shows waste treatment cost for both processing seasons for both actual operating conditions and assuming 365 days per year operation at full capacity.

It should be noted that the reused water has a value which has not been credited to the capital or operating cost of the treatment plant. Assuming that the operating cost of the reuse pumps and the operating cost of well pumps capable of delivering the same quantity of water would be the same, then a capital credit of $15,000 should be applied to the reuse system as the cost to replace the reuse system with an equivalent water well.

TABLE 15

OPERATION AND MAINTENANCE COST

1968-69 Citrus Processing Season

Three Operators @ $8,000/year	$ 24,000
Maintenance for season	6,000
Ammonia 58,000 lbs @ 9¢/lb	5,200
Phosphoric Acid 40,000 lbs @ 5.85¢/lb	2,340
Lime 240 tons @ $22/ton	5,300
Electricity (1.7×10^6 Kwh @ 1¢/Kwh)	17,000
TOTAL	$ 59,840

1969-70 Citrus Processing Season

Three Operators @ $8,000/year	$ 24,000
Maintenance for season	6,000
Ammonia 128,000 lbs @ 9¢/lb	11,500
Phosphoric Acid 47,000 lbs @ 6¢/lb	2,700
Electricity (1.7×10^6 Kwh @ 1¢/Kwh)	17,000
TOTAL	$ 61,200

TABLE 16

WASTE TREATMENT COST

1968-69 Citrus Processing Season

	Total Cost	¢ per box	¢ per ton	¢/lb BOD
Actual	$ 115,840	2.1	47.6	8.1
Full Capacity*	$ 161,680	0.55	12.2	1.3

1969-70 Citrus Processing Season

	Total Cost	¢ per box	¢ per ton	¢/lb BOD
Actual	$ 117,200	1.5	33.3	3.2
Full Capacity*	$ 164,400	0.56	12.4	1.3

*Assuming 365 days per year operation at full capacity.

SECTION VIII

ACKNOWLEDGEMENT

Numerous persons contributed time and effort to make this project successful. First of all Mr. James H. Bock, General Manager, and Mr. James W. Hayes, Plant Manager, of Winter Garden Citrus Products Cooperative should be acknowledged for their close cooperation throughout the project. Mr. Hayes was also project director and directly involved in guiding the project from start to finish.

Mr. Less Barr, Chief Plant Operator, deserves special recognition for the numerous hours he spent insuring that the treatment plant operated properly. Mr. Al Garner of Winter Garden Citrus also deserves special recognition for his assistance throughout the project.

Special recognition also goes to Dr. Richard H. Jones of Environmental Engineering, Inc., technical director of the grant, who designed the treatment system and directed the research program. During the first season of operation, Mr. Victor W. Randecker was engineer in charge of plant operation and personally conducted all chemical analyses on site. Mr. Marvin Hamlin performed the same task during the second season of operation. Without them the project would not have been successful.

The support of the project by the Office of Research, Industrial Pollution Control Program under the direction of Mr. William J. Lacy and Mr. H. G. Keeler, program manager, Environmental Protection Agency, and Dr. David Hill, the grant project officer, is acknowledged with sincere thanks.

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SECTION XI

GLOSSARY OF TERMS AND ABBREVIATIONS

ACTIVATED SLUDGE - Sludge floc produced in raw or settled wastewater by the growth of zoogleal bacteria and other organisms in the presence of dissolved oxygen and accumulated in sufficient concentration by returning floc previously formed.

ACTIVATED SLUDGE PROCESS - A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and wasted or returned to the process as needed.

AERATION - The bringing about of intimate contact between air and a liquid by one or more of the following methods: (a) spraying the liquid in the air, (b) bubbling air through the liquid, (c) agitating the liquid to promote surface absorption of air.

AERATOR - A device that promotes aeration.

AEROBIC DIGESTION - Digestion of suspended organic matter by means of aeration.

AEROBIC TREATMENT - A biological treatment process conducted in the presence of oxygen.

ALUM - Aluminum sulfate; a coagulant.

AMMONIA NITROGEN (AN) - All nitrogen existing as ammonium ion.

BAROMETRIC LEG WATER - That water used in the formation of a vacuum.

BIOCHEMICAL OXYGEN DEMAND (BOD) - The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions.

CHEMICAL OXYGEN DEMAND (COD) - A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with biochemical oxygen demand. Also known as OC and DOC, oxygen consumed and dichromate oxygen consumed, respectively.

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CLARIFIER - A tank or basin in which quiescent conditions are approached sufficiently for a portion of the suspended solids to be removed by gravity settling.

COAGULANT - A compound responsible for coagulation; a floc-forming agent.

COAGULANT AID - Any chemical or substance used to assist or modify coagulation.

COAGULATION - In water and wastewater treatment, the destabilization and initial aggregation of colloidal and fined divided suspended matter by the addition of a floc-forming chemical or by biological processes.

COLLOIDAL PARTICLES - Finely divided solids which will not settle but may be removed by coagulation or biochemical action or membrane filtration.

COMPLETE MIXED ACTIVATED SLUDGE - An activated sludge process in which the influent is applied throughout the aeration basin.

CONCENTRATED WASTEWATER - Wastewater containing BOD concentrations greater than 1000 mg/l.

DETENTION TIME - The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

DIGESTION - The biological decomposition of organic matter in sludge, resulting in partial gasification, liquefaction, and mineralization.

DISSOLVED OXYGEN (D.O.) - Uncombined oxygen in solution in a liquid.

EFFLUENT (EFF.) - Liquid flowing out of a containing space.

EXCESS ACTIVATED SLUDGE - The sludge produced in an activated sludge treatment plant that is not needed to maintain the process and is withdrawn from circulation.

GALLONS PER DAY (GPD) - A common volume per unit time expression of liquid flowrate.

INFLUENT (INF.) - Liquid flowing into a containing space.

MILLIGRAMS PER LITER (mg/l) - The mass of a substance in milligrams contained in one liter of liquid.

MILLION GALLONS PER DAY (MGD) - A common volume per unit time expression of liquid flowrate.

MIXED LIQUOR SUSPENDED SOLIDS (MLSS) - The concentration in milligrams per liter by dry weight of solids in the activated sludge unit.

NUTRIENT - A substance which promotes cellular growth in organisms.

ORGANIC NITROGEN (ON) - All nitrogen existing in organic compounds.

pH - The negative logarithm of the hydrogen ion concentration of a solution; a measure of the acidity of alkalinity of a solution.

RETURN SLUDGE - Sludge which has settled in the final clarifier and is returned to the activated sludge unit.

SLUDGE - Accumulated solids which have been separated from wastewater and which contain a high enough moisture content to have a semi-liquid form.

SLUDGE BLANKET - The interface formed in a clarifier between the region of clarified fluid and the region of uniform suspension.

SLUDGE THICKENING - Reduction of the moisture content of a sludge resulting in a reduced volume.

SLUDGE VOLUME INDEX (SVI) - The ratio of the volume in milliliters of sludge settled from a 1,000-ml sample in 30 min to the concentration of mixed liquor in milligrams per liter multiplied by 1,000.

SLUG - A high concentration of a substance in a flowing liquid; generally beginning and ending abruptly and lasting for a relatively short period of time.

SUPERNATANT LIQUOR - The liquid overlying deposited solids.

SURGE TANK - A basin or chamber which provides either positive or negative pressure relief to a pumping system.

SUSPENDED SOLIDS (SS) - Those particles in a liquid which are not in solution and can be removed by filtration.

TOTAL NITROGEN (TN) - The sum of nitrogen existing in the forms of ammonia nitrogen and organic nitrogen.

VOLATILE SUSPENDED SOLIDS (VSS) - The quantity of suspended solids in wastewater lost on ignition at 600°C.

WASTE SLUDGE - See excess activated sludge.

SECTION XII

APPENDICES

A. COLLECTED AND AVERAGED DATA, 1968-69 SEASON

Table A-1 Wastewater Flow and Fruit Processed

Table A-2 Average Addition of Nutrients to the Influent

Table A-2s Statistical Analysis of Nutrient Addition to Influent

Table A-3 Average Nutrient Analyses of Influent and Effluents

Table A-3s Statistical Analysis of Nutrients in Influent and Effluents

Table A-4 Average Organic and Solids Analyses of Influent and Biologically Treated Effluent

Table A-4s Statistical Analysis of Influent and Biologically Treated Effluent Organic and Solids Concentrations

Table A-5 Activated Sludge Process Loading Rates

Table A-5s Statistical Analysis of Activated Sludge Process Loading Rates, Daily Figures

Table A-6 Centrifuge Solids

B. COLLECTED AND AVERAGED DATA, 1969-70 SEASON

Table B-1 Wastewater Flow and Fruit Processed

Table B-2 Average Addition of Nutrients to the Influent

Table B-2s Statistical Analysis of Nutrient Addition to Influent

Table B-3 Average Organic and Solids Analyses of Influent and Effluent

Table B-3s Statistical Analysis of Influent and Effluent Organic and Solids Concentrations

Table B-4 Activated Sludge Process Loading Rates
Table B-4s Statistical Analysis of Activated Sludge Process Loading Rates
Table B-5 Aerobic Sludge Digester
Table B-5s Statistical Analysis of Aerobic Sludge Digester
Table B-6 Centrifuge Solids

C. PHOTOGRAPHS

Figure C-1 Aerial View of Waste Treatment Plant
Figure C-2 Aerobic Digester (Modified Lime Treatment Plant)
Figure C-3 Complete Mix Activated Sludge Unit
Figure C-4 Clarifier

APPENDIX A

COLLECTED AND AVERAGED DATA, 1968 - 69 SEASON

TABLE A-1

WASTEWATER FLOW AND FRUIT PROCESSED

Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes	Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes
1/19/69	0.8	41.2	0.0	2/26/69	1.1	36.0	0.0
1/20/69	0.4	0.0	0.0	2/27/69	1.1	29.7	0.0
1/21/69	1.0	60.9	0.0	2/28/69	0.9	47.5	0.0
1/22/69	1.2	59.6	0.0	3/1/69	0.3	5.9	0.0
1/23/69	1.0	61.0	0.0	3/2/69	0.1	0.0	0.0
1/24/69	1.0	59.1	0.0	3/3/69	0.1	0.0	0.0
1/25/69	1.0	58.0	0.0	3/4/69	1.0	38.7	0.0
1/26/69	0.4	0.0	0.0	3/5/69	1.2	30.9	0.0
1/27/69	1.3	56.2	0.0	3/6/69	1.0	47.2	0.0
1/28/69	1.2	57.6	0.0	3/7/69	0.8	47.4	0.0
1/29/69	1.2	54.2	0.0	3/8/69	0.7	10.6	0.0
1/30/69	1.2	54.0	0.0	3/9/69	0.4	0.0	0.0
1/31/69	1.1	52.3	0.0	3/10/69	0.6	28.7	0.0
2/1/69	1.1	57.3	0.0	3/11/69	0.6	30.6	0.0
2/2/69	0.5	0.0	0.0	3/12/69	0.7	30.5	0.0
2/3/69	1.0	55.0	0.0	3/13/69	0.9	29.3	0.0
2/4/69	1.0	45.5	0.0	3/14/69	1.1	37.8	0.0
2/5/69	1.1	56.5	0.0	3/15/69	0.7	3.7	0.0
2/6/69	1.0	54.6	0.0	3/16/69	0.4	0.0	0.0
2/7/69	1.0	55.8	0.0	3/17/69	0.2	0.0	0.0
2/8/69	1.0	52.5	0.5	3/18/69	0.6	12.4	0.0
2/9/69	0.3	0.0	0.0	3/19/69	0.1	0.0	0.0
2/10/69	1.2	57.2	0.0	3/20/69	1.0	16.4	21.1
2/11/69	0.9	55.1	0.0	3/21/69	0.8	30.2	6.2
2/12/69	0.9	54.8	0.0	3/22/69	0.5	14.4	0.0
2/13/69	0.9	45.2	8.8	3/23/69	0.1	0.0	0.0
2/14/69	0.9	46.9	4.4	3/24/69	0.1	0.0	0.0
2/15/69	0.4	47.8	0.0	3/25/69	0.8	15.5	21.9
2/16/69	0.1	0.0	0.0	3/26/69	0.8	19.0	8.7
2/17/69	0.5	35.7	0.0	3/27/69	0.8	17.0	13.5
2/18/69	1.1	48.3	0.0	3/28/69	0.9	16.9	22.4
2/19/69	0.9	43.1	0.0	3/29/69	0.7	7.6	6.5
2/20/69	1.0	48.0	0.0	3/30/69	0.5	0.0	0.0
2/21/69	1.0	47.5	0.0	3/31/69	0.3	9.8	13.2
2/22/69	1.4	50.6	0.0	4/1/69	0.9	15.7	22.0
2/23/69	0.3	0.0	0.0	4/2/69	0.9	18.0	21.3
2/24/69	0.9	46.0	0.0	4/3/69	1.1	15.8	23.1
2/25/69	0.9	36.1	0.0	4/4/69	1.2	16.4	19.9

*One Box is 90 pounds of fruit.

TABLE A-1
(Continued)

WASTEWATER FLOW AND FRUIT PROCESSED

Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes	Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes
4/5/69	0.7	0.0	0.0	5/13/69	1.4	61.9	0.0
4/6/69	0.3	0.0	0.0	5/14/69	1.5	59.7	0.0
4/7/69	0.2	0.0	0.0	5/15/69	1.4	45.8	0.0
4/8/69	1.1	17.6	21.7	5/16/69	1.4	54.0	0.0
4/9/69	0.7	18.7	24.9	5/17/69	1.2	30.3	0.0
4/10/69	1.5	17.3	24.5	5/18/69	0.2	0.0	0.0
4/11/69	1.0	14.2	20.0	5/19/69	1.5	59.1	0.0
4/12/69	1.1	0.0	0.0	5/20/69	1.3	7.0	0.0
4/13/69	0.0	0.0	0.0	5/21/69	1.3	59.8	0.0
4/14/69	1.2	0.0	0.0	5/22/69	1.3	42.7	0.0
4/15/69	1.0	18.6	25.3	5/23/69	1.3	46.6	0.0
4/16/69	1.0	19.4	21.4	5/24/69	0.2	30.4	0.0
4/17/69	1.2	15.1	19.0	5/25/69	0.0	0.0	0.0
4/18/69	0.8	10.7	9.1	5/26/69	1.3	63.3	0.0
4/19/69	0.1	0.0	0.0	5/27/69	1.3	62.1	0.0
4/20/69	0.0	0.0	0.0	5/28/69	1.2	61.5	0.0
4/21/69	1.2	0.0	0.0	5/29/69	1.3	61.5	0.0
4/22/69	1.2	21.3	24.2	5/30/69	1.3	61.9	0.0
4/23/69	1.0	0.0	29.8	5/31/69	1.4	30.4	0.0
4/24/69	1.0	13.1	25.1	6/1/69	0.0	0.0	0.0
4/25/69	1.0	14.5	28.6	6/2/69	1.2	61.3	0.0
4/26/69	0.9	0.0	6.0	6/3/69	1.4	48.1	0.0
4/27/69	0.1	0.0	0.0	6/4/69	1.4	46.0	0.0
4/28/69	1.3	34.4	15.4	6/5/69	1.4	50.4	0.0
4/29/69	1.3	38.9	0.0	6/6/69	1.3	54.4	0.0
4/30/69	1.0	53.4	0.0	6/7/69	1.0	7.9	0.0
5/1/69	1.1	60.6	0.0	6/8/69	0.6	0.0	0.0
5/2/69	1.0	56.8	0.0	6/9/69	1.3	54.4	0.0
5/3/69	1.2	24.6	0.0	6/10/69	1.3	58.0	0.0
5/4/69	0.0	0.0	0.0	6/11/69	1.5	54.5	0.0
5/5/69	1.3	61.8	0.0	6/12/69	1.4	45.7	0.0
5/6/69	1.3	62.9	0.0	6/13/69	1.5	54.4	0.0
5/7/69	1.2	55.0	0.0	6/14/69	0.6	15.8	0.0
5/8/69	1.2	58.4	0.0	6/15/69	0.0	0.0	0.0
5/9/69	1.4	59.4	0.0	6/16/69	1.5	61.5	0.0
5/10/69	1.0	31.1	0.0	6/17/69	0.8	59.4	0.0
5/11/69	0.2	0.0	0.0	6/18/69	1.3	57.8	0.0
5/12/69	1.3	56.5	0.0	6/19/69	0.1	0.0	0.0

*One box is 90 pounds of fruit

TABLE A-1
(Continued)

WASTEWATER FLOW AND FRUIT PROCESSED

Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes	Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes
6/20/69	1.2	44.0	0.0	6/23/69	1.2	57.2	0.0
6/21/69	1.0	28.1	0.0	6/24/69	1.3	52.1	0.0
6/22/69	0.1	0.0	0.0				

TABLE A-2

AVERAGE ADDITION OF NUTRIENTS TO THE INFLUENT

Month, 1969	Pounds/Day N	Pounds/Day P
January	282	90
February	218	97
March	68	36
April	116	42
May	614	123
June	455	91

TABLE A-2s

STATISTICAL ANALYSIS OF NUTRIENT ADDITION TO INFLUENT

	Data Points	Mean	Standard Deviation
Pounds of Nitrogen, daily figures	162	296	290
Pounds of Nitrogen, monthly averages	6	292	190
Pounds of Phosphorus, daily figures	161	79	88
Pounds of Phosphorus, monthly averages	6	80	31

TABLE A-3

AVERAGE NUTRIENT ANALYSIS OF INFLUENT AND EFFLUENT

MONTH 1969	TN	AN	ON	NO_3+NO_2 -N	NO_2-N	NO_3-N	Total P	Ortho P	Total P Filtered	Ortho P Filtered
				INFLUENT*						
February	35.9	15.7	19.8	0.20	0.02	0.18	10.95	2.97	3.50	1.92
March	24.5	8.6	15.9	0.23	0.08	0.14	7.49	2.28	1.62	0.82
April	23.2	11.7	12.6	0.34	0.07	0.26	5.60	2.96	3.26	1.28
May	60.8	32.58	30.58	0.25	0.07	0.17	8.29	6.97	5.09	3.46
June	50.32	22.13	29.01	0.21	0.07	0.14	9.20	7.63	5.47	4.71
July	32.5	16.9	15.40	0.25	0.05	0.19	19.60	8.34	8.16	2.29
				BIOLOGICALLY TREATED EFFLUENT*						
February	4.33	0.39	3.94	0.02	0.01	0.01	4.54	1.80	3.11	1.86
March	4.05	0.40	3.35	0.04	0.02	0.02	7.69	1.16	0.86	0.38
April	3.80	0.35	3.45	0.09	0.02	0.07	1.95	0.47	0.55	0.13
May	4.46	1.32	3.15	0.03	0.01	0.02	1.45	1.18	0.98	0.83
June	2.77	0.76	2.27	0.02	0.01	0.02	1.90	1.60	0.99	0.75
July	1.69	0.23	1.46	0.00	0.00	0.00	0.33	0.31	0.26	0.23
				CHEMICALLY TREATED EFFLUENT*						
February	4.21	0.53	3.69	0.03	0.01	0.02	2.15	1.03	0.81	0.13
March	7.93	0.72	7.21	0.09	0.03	0.05	5.35	1.03	1.48	0.51
April	6.21	0.61	5.60	0.10	0.02	0.08	1.72	0.69	0.73	0.23
May	4.13	1.22	2.97	0.02	0.01	0.02	0.75	0.50	0.43	0.25
June	2.25	0.23	2.32	0.02	0.00	0.02	0.54	0.30	0.18	0.12

*All results expressed as mg/l
TN = Total Nitrogen
AN = Ammonia Nitrogen
ON = Organic Nitrogen

TABLE A-3s

STATISTICAL ANALYSIS OF NUTRIENTS IN INFLUENT AND EFFLUENTS

		Data Points	Mean mg/l	Standard Deviation mg/l
TN	Influent	50	39.82	23.11
	Biologically Treated Effluent	51	3.80	2.15
Daily Figures	Chemically Treated Effluent	46	4.95	3.41
TN	Influent	6	37.87	14.86
	Biologically Treated Effluent	6	3.52	1.05
Monthly Averages	Chemically Treated Effluent	5	4.95	2.18
AN	Influent	50	18.13	11.54
	Biologically Treated Effluent	51	0.67	1.38
Daily Figures	Chemically Treated Effluent	46	0.69	1.45
AN	Influent	6	17.94	8.53
	Biologically Treated Effluent	6	0.58	0.44
Monthly Averages	Chemically Treated Effluent	5	0.66	0.36
ON	Influent	50	22.05	14.73
	Biologically Treated Effluent	51	3.09	1.76
Daily Figures	Chemically Treated Effluent	46	4.29	3.12
ON	Influent	6	20.55	7.54
	Biologically Treated Effluent	6	2.94	0.92
Monthly Averages	Chemically Treated Effluent	5	4.36	2.01

TABLE A-3s
(Continued)

STAT STICAL ANALYSIS OF NUTRIENTS IN INFLUENT AND EFFLUENT

		Data Points	Mean mg/l	Standard Deviation mg/l
NO_3+NO_2-N	Influent	50	0.24	0.09
	Biologically Treated Effluent	51	0.04	0.04
Daily Figures	Chemically Treated Effluent	46	0.04	0.06
NO_3+NO_2-N	Influent	6	0.25	0.05
	Biologically Treated Effluent	6	0.33	0.33
Monthly Averages	Chemically Treated Effluent	5	0.05	0.52
NO_2-N	Influent	50	0.06	0.03
	Biologically Treated Effluent	51	0.01	0.08
Daily Figures	Chemically Treated Effluent	46	0.01	0.02
NO_2-N	Influent	6	0.06	0.02
	Biologically Treated Effluent	6	0.01	0.01
Monthly Averages	Chemically Treated Effluent	5	0.01	0.04
NO_3-N	Influent	50	0.18	0.08
	Biologically Treated Effluent	51	0.03	0.03
Daily Figures	Chemically Treated Effluent	46	0.03	0.05
NO_3-N	Influent	6	0.18	0.04
	Biologically Treated Effluent	6	0.02	0.02
Monthly Averages	Chemically Treated Effluent	5	0.04	0.08

TABLE A-3s
(Continued)

STATISTICAL ANALYSIS OF NUTRIENTS IN INFLUENT AND EFFLUENT

		Data Points	Mean mg/l	Standard Deviation mg/l
Total P Daily Figures	Influent	50	8.30	5.52
	Biologically Treated Effluent	51	1.07	4.12
	Chemically Treated Effluent	46	0.07	2.39
Total P Monthly Averages	Influent	6	10.19	4.94
	Biologically Treated Effluent	6	2.98	2.69
	Chemically Treated Effluent	5	2.10	1.93
Ortho P Daily Figures	Influent	50	4.97	4.23
	Biologically Treated Effluent	51	1.23	1.38
	Chemically Treated Effluent	46	0.70	0.64
Ortho P Monthly Averages	Influent	6	5.19	2.74
	Biologically Treated Effluent	6	1.09	0.58
	Chemically Treated Effluent	5	0.71	0.32
Total P Filtered Daily Figures	Influent	50	4.05	3.86
	Biologically Treated Effluent	51	1.26	1.26
	Chemically Treated Effluent	46	0.70	0.67
Total P Filtered Monthly Averages	Influent	6	4.52	2.26
	Biologically Treated Effluent	6	1.12	1.02
	Chemically Treated Effluent	5	0.73	0.49

TABLE A-3s
(Continued)

STATISTICAL ANALYSIS OF NUTRIENTS IN INFLUENT AND EFFLUENT

		Data Points	Mean mg/l	Standard Deviation mg/l
Ortho P Filtered	Influent	50	2.59	3.00
	Biologically Treated Effluent	51	0.75	1.10
Daily Figures	Chemically Treated Effluent	46	0.24	0.22
Ortho P Filtered	Influent	6	2.41	1.45
	Biologically Treated Effluent	6	0.70	0.63
Monthly Averages	Chemically Treated Effluent	5	0.25	0.16

TN = Total Nitrogen
AN = Ammonia Nitrogen
ON = Organic Nitrogen

TABLE A-4

AVERAGE ORGANIC AND SOLIDS ANALYSES OF INFLUENT AND BIOLOGICALLY TREATED EFFLUENT

MONTH 1969	BOD*		COD*		SS*		VSS		pH	
	INF.	EFF.	INF.	EFF.	INF.	EFF.	INF.	EFF.	INF.	EFF.
January	827	54	1960	267	162	107	152	96	10.3	7.7
February	1438	23	2375	159	338	269	200	230	11.2	7.8
March	1458	63	3551	276	450	969	333	753	9.8	7.7
April	835	44	1545	410	449	397	148	227	9.8	7.9
May	1139	30	2571	122	197	45	195	35	9.8	7.8
June	983	12	2132	90	146	18	76	14	10.3	8.0
July	630	5	3895	92	609	13	373	9	9.4	7.9

*Expressed as mg/l

TABLE A-4s

STATISTICAL ANALYSIS OF INFLUENT AND BIOLOGICALLY TREATED EFFLUENT ORGANIC AND SOLIDS CONCENTRATIONS

		Data Points	Mean	Standard Deviation
BOD* Daily Figures	INF.	59	1167	775
	EFF.	58	29	28
BOD* Monthly Averages	INF.	7	1044	293
	EFF.	7	33	20
COD* Daily Figures	INF.	59	2469	1459
	EFF.	59	189	174
COD* Monthly Averages	INF.	7	2576	790
	EFF.	7	202	111
SS* Daily Figures	INF.	59	312	344
	EFF.	58	285	419
SS* Monthly Averages	INF.	7	336	163
	EFF.	7	260	319
VSS* Daily Figures	INF.	57	190	158
	EFF.	56	220	331
VSS* Monthly Averages	INF.	7	211	98
	EFF.	7	195	244
pH Daily Figures	INF.	59	10.1	1.2
	EFF.	58	7.8	0.2
pH Monthly Averages	INF.	7	10.1	0.5
	EFF.	7	7.8	0.1

*Expressed as mg/l

TABLE A-5

ACTIVATED SLUDGE PROCESS LOADING RATES

Date	BOD	Flow Rate MGD	Avg.MLSS mg/l	lbs.BOD/ lbs.MLSS
1/28/69	750	1.2	1378	0.220
1/29/69	930	1.2	1505	0.267
1/30/69	800	1.2	1605	0.215
2/2/69	1170	0.5	1750	0.120
2/4/69	930	1.0	2385	0.140
2/5/69	2160	1.1	2815	0.304
2/6/69	3180	1.0	3030	0.378
2/10/69	390	1.2	3040	0.055
2/11/69	675	0.9	3260	0.067
2/12/69	900	0.9	3396	0.086
2/13/69	2340	0.9	4268	0.178
2/18/69	480	1.1	2720	0.070
2/19/69	1350	0.9	2285	0.191
2/20/69	2685	1.0	3045	0.318
2/21/69	1455	1.1	3050	0.189
2/25/69	400	1.0	3420	0.378
2/26/69	625	1.1	3140	0.079
2/27/69	2050	1.0	3225	0.229
2/28/69	2220	0.9	4177	0.172
3/4/69	1000	1.0	2970	0.091
3/5/69	435	1.2	3815	0.049
3/6/69	1170	1.0	4165	0.101
3/7/69	3250	0.8	3445	0.272
3/12/69	1725	0.7	3785	0.115
3/13/69	2250	0.9	2987	0.242
3/14/69	1200	1.1	3040	0.156
3/25/69	1200	0.8	5000*	0.139
3/26/69	900	0.8	6250*	0.083
4/1/69	400	0.9	5545	0.023
4/2/69	650	0.9	4580	0.046
4/10/69	1200	1.5	3865	0.166
4/17/69	1275	1.2	3200	0.170
4/22/69	600	1.2	2397	0.107
4/23/69	600	1.0	1850	0.117
4/30/69	1125	1.0	2003	0.200

*Only one aeration tank in use.

TABLE A-5
(Continued)

ACTIVATED SLUDGE PROCESS LOADING RATES

Date	BOD mg/l	Flow Rate MGD	Avg.MLSS mg/l	lbs.BOD/ lbs.MLSS
5/5/69	750	1.3	2079	0.168
5/6/69	600	1.3	2265	0.123
5/7/69	750	1.2	2160	0.149
5/13/69	780	1.4	3140	0.124
5/14/69	1650	1.5	3485	0.254
5/15/69	780	1.4	4580	0.085
5/20/69	2200	1.3	6374	0.160
5/21/69	305	1.3	4950	0.029
5/22/69	2075	1.3	5086	0.189
5/23/69	1500	1.3	6290	0.111
6/2/69	480	1.2	4939	0.042
6/3/69	580	1.4	4770	0.059
6/4/69	640	1.4	4930	0.065
6/5/69	920	1.4	5542	0.083
6/6/69	2160	1.4	5865	0.184
6/7/69	3300	1.0	6985	0.169
6/8/69	270	0.6	5080	0.014
6/9/69	855	1.3	5110	0.078
6/10/69	525	1.3	5510	0.044
6/11/69	780	1.5	5705	0.073
6/12/69	720	1.4	6150	0.059

TABLE A-5s

STATISTICAL ANALYSIS OF ACTIVATED SLUDGE PROCESS LOADING RATES
DAILY FIGURES

	Data Points	Mean	Standard Deviation
BOD,mg/l	56	1198	775
Flow Rate, MGD	56	1.1	0.2
Ave. MLSS, mg/l	56	3810	1430
lbs BOD/lbs MLSS	56	0.143	0.086

TABLE A-6

CENTRIFUGE PERCENT SOLIDS

Date	Influent % Solids	Effluent % Solids	Cake % Solids	Influent Feed Rate GPM	Coagulant Type	Coagulant Feed Rate GPM	Dispersion Water Feed Rate, GPM
2/18/69	3.12	0.28	20.6	-	-	-	-
2/21/69	12.90	3.45	50.6	-	-	-	-
2/21/69	3.52	0.48	25.2	-	-	-	-
2/24/69	10.40	4.27	45.0	-	-	-	-
2/24/69	5.03	2.35	50.9	-	-	-	-
2/25/69	8.76	1.48	40.4	-	-	-	-
2/25/69	2.32	1.23	22.5	-	-	-	-
3/4/69	3.81	1.18	36.4	-	-	-	-
3/11/69	3.81	1.18	36.4	-	-	-	-
3/13/69	3.37	1.24	30.0	25	-	-	-
3/13/69	3.54	1.58	27.3	32	-	-	-
3/13/69	4.24	2.07	29.0	38	-	-	-
3/13/69	3.44	1.72	47.5	25	-	-	-
3/14/69	2.71	1.58	28.4	-	-	-	-
3/29/69	8.16	2.76	31.6	-	-	-	-
4/11/69	5.39	4.10	51.8	-	-	-	-
4/12/69	2.42	1.79	49.4	-	-	-	-
4/12/69	3.49	2.82	55.6	-	-	-	-
4/12/69	2.95	2.18	57.8	-	-	-	-
4/16/69	5.40	4.10	51.8	-	-	-	-
4/16/69	4.26	0.82	48.0	-	-	-	-
4/16/69	4.10	1.03	6.3	-	-	-	-
4/17/69	7.00	1.87	10.8	-	-	-	-
4/17/69	7.59	2.63	18.8	-	-	-	-
4/18/69	5.60	2.12	13.1	-	-	-	-
4/18/69	6.53	2.58	12.1	-	-	-	-
4/18/69	7.16	2.82	9.9	-	-	-	-
4/22/69	5.64	3.26	9.2	25			
4/22/69	5.25	1.45	8.6	25	Nalco 672	1.0	4
4/23/69	6.00	0.30	4.3	25	Nalco 672	1.0	6
4/23/69	7.86	0.83	16.7	25	-	0.0	0
4/23/69	8.37	4.06	18.1	40	-	0.0	0
4/23/69	3.54	1.12	8.6	40	Nalco 672	1.0	5
4/23/69	5.84	1.18	7.0	40	Nalco 672	0.5	5
4/25/69	7.05	3.83	31.2	40	-	0.0	0
4/25/69	3.36	1.09	12.5	40	Nalco 672	0.5	5

TABLE A-6
(Continued)

CENTRIFUGE PERCENT SOLIDS

Date	Influent % Solids	Effluent % Solids	Cake % Solids	Influent Feed Rate GPM	Coagulant Type	Coagulant Feed Rate GPM	Dispersion Water Feed Rate, GPM
5/19/69	0.87	0.40	13.1	40	Nalco 672	0.5	10
5/21/69	1.47	0.65	4.6	40	Nalco 672	0.5	10
5/21/69	1.45	0.78	4.0	40	Nalco 672	0.9	10
5/23/69	2.49	0.72	13.4	40	Nalco 672	0.9	10
5/23/69	2.46	0.88	15.7	50	Nalco 672	0.9	10
5/23/69	2.78	0.74	13.9	40	Nalco 672	0.5	10
5/28/69	2.99	0.65	6.5	40	Nalco 672	0.5	10
5/28/69	2.74	0.66	6.4	40	Nalco 672	0.25	10
5/28/69	2.51	0.60	6.5	40	Nalco 672	0.25	5
6/11/69	3.71	0.84	17.6	-	-	-	-
6/13/69	2.40	0.21	15.0	-	-	-	-
6/17/69	4.44	0.71	25.2	40	Cat. Floc	0.25	5
6/17/69	2.64	0.36	16.4	40	Cat. Floc	0.25	5
6/24/69	5.24	0.66	31.4	40	Nalco 607	0.25	5
6/25/69	4.35	2.34	17.0	40	Nalco 607	0.25	5
6/25/69	1.86	1.06	5.2	40	-	0.0	0
6/27/69	1.77	0.35	8.3	20	-	0.0	0
6/27/69	1.48	0.06	7.1	20	Nalco 607	0.5	5
6/27/69	1.40	0.05	6.8	20	Nalco 607	0.25	5
6/28/69	2.74	0.87	9.0	20	Nalco 607	0.25	5
7/2/69	1.81	0.72	9.9	20	Nalco 607	0.25	5
7/2/69	2.00	0.65	5.4	20	Nalco 607	1.25	5
7/3/69	1.76	0.44	7.4	20	-	-	5

APPENDIX B COLLECTED AND AVERAGED DATA 1969-70 SEASON

TABLE B-1

WASTEWATER FLOW AND FRUIT PROCESSED

Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes	Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes
11/11/69	-	6.3	0.0	12/19/69	0.9	32.6	0.0
11/12/69	-	7.3	0.0	12/20/69	0.8	17.2	0.0
11/13/69	-	6.7	0.0	12/21/69	0.1	0.0	0.0
11/14/69	-	7.7	0.0	12/22/69	1.1	39.4	0.0
11/15/69	-	0.0	0.0	12/23/69	0.9	22.4	0.0
11/16/69	-	0.0	0.0	12/24/69	0.1	0.0	0.0
11/17/69	-	8.7	0.0	12/25/69	0.1	0.0	0.0
11/18/69	-	9.4	0.0	12/26/69	0.1	0.0	0.0
11/19/69	-	9.7	0.0	12/27/69	0.9	30.3	0.0
11/20/69	-	11.6	0.0	12/28/69	1.0	34.0	0.0
11/21/69	-	12.1	0.0	12/29/69	1.3	48.7	0.0
11/22/69	-	6.4	0.0	12/30/69	1.3	52.1	0.0
11/23/69	-	0.0	0.0	12/31/69	1.3	56.3	0.0
11/24/69	-	16.9	0.0	1/1/70	1.6	55.6	0.0
11/25/69	-	21.3	0.0	1/2/70	1.5	45.2	0.0
11/26/69	-	19.4	0.0	1/3/70	0.5	6.7	0.0
11/27/69	-	0.0	0.0	1/4/70	0.1	0.0	0.0
11/28/69	-	20.2	0.0	1/5/70	1.3	48.1	0.0
11/29/69	-	17.6	0.0	1/6/70	1.2	31.0	0.0
11/30/69	-	0.0	0.0	1/7/70	0.4	0.0	0.0
12/1/69	-	19.6	0.0	1/8/70	1.4	49.6	0.0
12/2/69	-	22.4	0.0	1/9/70	1.6	46.8	0.0
12/3/69	-	20.7	0.0	1/10/70	1.7	48.8	0.0
12/4/69	-	22.1	0.0	1/11/70	1.9	49.5	0.0
12/5/69	-	18.5	0.0	1/12/70	1.9	53.5	0.0
12/6/69	-	14.8	0.0	1/13/70	1.7	54.7	0.0
12/7/69	-	0.0	0.0	1/14/70	1.7	54.6	0.0
12/8/69	-	26.0	0.0	1/15/70	1.6	60.3	0.0
12/9/69	-	19.6	0.0	1/16/70	1.4	39.8	0.0
12/10/69	-	7.3	0.0	1/17/70	0.9	22.0	0.0
12/11/69	-	20.5	0.0	1/18/70	1.7	60.0	0.0
12/12/69	-	33.7	0.0	1/19/70	1.5	62.3	0.0
12/13/69	-	8.3	0.0	1/20/70	1.6	60.8	0.0
12/14/69	-	0.0	0.0	1/21/70	1.6	62.0	0.0
12/15/69	-	33.6	0.0	1/22/70	1.7	67.8	0.0
12/16/69	-	32.6	0.0	1/23/70	1.6	64.9	0.0
12/17/69	-	32.8	0.0	1/24/70	1.6	61.4	0.0
12/18/69	-	33.1	0.0	1/25/70	1.6	65.7	0.0

*One box is 90 pounds of fruit

TABLE B-1
(Continued)

WASTEWATER FLOW AND FRUIT PROCESSED

Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes	Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes
1/26/70	1.6	65.1	0.0	3/4/70	1.3	38.1	8.6
1/27/70	1.8	61.3	0.0	3/5/70	1.5	30.8	18.5
1/28/70	1.7	67.4	0.0	3/6/70	1.4	37.3	0.0
1/29/70	1.6	62.7	0.0	3/7/70	0.2	0.0	0.0
1/30/70	1.6	58.0	0.0	3/8/70	0.1	0.0	0.0
1/31/70	1.2	50.6	0.0	3/9/70	1.2	16.1	20.1
2/1/70	1.7	56.4	0.0	3/10/70	1.4	36.2	0.0
2/2/70	1.3	24.4	0.0	3/11/70	1.4	17.0	23.9
2/3/70	0.8	0.0	0.0	3/12/70	1.5	34.3	19.1
2/4/70	1.5	35.0	0.0	3/13/70	1.3	36.2	13.8
2/5/70	1.7	57.6	0.0	3/14/70	1.4	6.0	1.4
2/6/70	1.2	60.5	0.0	3/15/70	0.3	0.0	0.0
2/7/70	0.9	61.1	0.0	3/16/70	0.4	10.3	0.0
2/8/70	0.9	60.7	0.0	3/17/70	1.1	11.7	18.0
2/9/70	1.1	56.4	0.0	3/18/70	1.2	10.5	20.5
2/10/70	1.0	60.7	0.0	3/19/70	0.9	9.0	1.7
2/11/70	0.9	59.7	0.0	3/20/70	1.0	6.1	11.2
2/12/70	1.3	63.8	0.0	3/21/70	0.1	0.0	0.0
2/13/70	1.0	59.2	0.0	3/22/70	0.1	0.0	0.0
2/14/70	1.1	55.0	0.0	3/23/70	0.1	0.0	0.0
2/15/70	1.3	53.3	0.0	3/24/70	0.1	0.0	0.0
2/16/70	1.6	28.6	0.0	3/25/70	0.9	2.9	9.7
2/17/70	1.0	10.6	0.0	3/26/70	0.1	0.0	4.1
2/18/70	1.0	36.8	0.0	3/27/70	0.1	0.0	0.0
2/19/70	1.5	59.8	0.0	3/28/70	0.1	0.0	0.0
2/20/70	1.4	59.2	0.0	3/29/70	0.1	0.0	0.0
2/21/70	1.4	57.8	0.0	3/30/70	0.1	0.0	0.0
2/22/70	0.4	0.0	0.0	3/31/70	0.4	0.0	0.0
2/23/70	1.2	49.0	0.0	4/1/70	0.4	0.0	0.0
2/24/70	1.3	50.8	0.0	4/2/70	0.4	0.0	3.8
2/25/70	1.3	47.4	0.0	4/3/70	0.4	0.0	0.0
2/26/70	1.2	33.7	0.0	4/4/70	0.1	0.0	0.0
2/27/70	1.4	32.1	0.0	4/5/70	0.1	0.0	0.0
2/28/70	0.8	47.3	0.0	4/6/70	0.1	0.0	0.0
3/1/70	0.1	0.0	0.0	4/7/70	0.1	0.0	0.0
3/2/70	0.7	24.8	0.0	4/8/70	1.0	28.1	0.0
3/3/70	1.4	45.9	0.0	4/9/70	1.0	33.2	0.0

*One box is 90 pounds of fruit

TABLE B-1
(Continued)

WASTEWATER FLOW AND FRUIT PROCESSED

Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes	Date	Flow Rate MGD	Oranges 1000 Boxes*	Grape-Fruit 1000 Boxes
4/10/70	0.4	11.5	0.0	5/19/70	1.5	55.2	0.0
4/11/70	0.4	0.0	0.0	5/20/70	1.4	53.8	0.0
4/12/70	0.1	0.0	0.0	5/21/70	1.4	54.4	0.0
4/13/70	0.7	24.9	0.0	5/22/70	1.5	52.8	0.0
4/14/70	1.4	38.5	0.0	5/23/70	1.4	51.8	0.0
4/15/70	1.3	43.1	0.0	5/24/70	1.6	55.1	0.0
4/16/70	1.2	41.4	0.0	5/25/70	1.6	53.7	0.0
4/17/70	1.2	46.0	0.0	5/26/70	1.2	49.7	0.0
4/18/70	0.4	2.3	3.5	5/27/70	1.4	51.4	0.0
4/19/70	0.1	0.0	0.0	5/28/70	1.5	56.1	0.0
4/20/70	1.3	54.0	0.0	5/29/70	1.5	52.3	0.0
4/21/70	1.5	55.8	0.0	5/30/70	0.7	18.7	0.0
4/22/70	1.4	52.5	0.0	5/31/70	0.1	0.0	0.0
4/23/70	1.4	53.9	0.0	6/1/70	1.0	36.3	0.0
4/24/70	1.5	56.3	0.0	6/2/70	1.4	59.1	0.0
4/25/70	1.4	49.1	0.0	6/3/70	1.4	51.6	0.0
4/26/70	0.4	0.0	0.0	6/4/70	1.5	54.3	0.0
4/27/70	1.3	59.4	0.0	6/5/70	1.2	57.3	0.0
4/28/70	1.4	56.1	0.0	6/6/70	1.4	54.5	0.0
4/29/70	1.5	59.5	0.0	6/7/70	1.5	56.8	0.0
4/30/70	1.3	55.5	0.0	6/8/70	1.7	53.0	0.0
5/1/70	1.4	59.6	0.0	6/9/70	1.6	52.7	0.0
5/2/70	1.7	57.3	0.0	6/10/70	1.6	50.8	0.0
5/3/70	1.4	55.5	0.0	6/11/70	1.6	52.9	0.0
5/4/70	1.5	54.8	0.0	6/12/70	1.6	58.2	0.0
5/5/70	1.1	55.2	0.0	6/13/70	1.7	58.9	0.0
5/6/70	1.2	57.9	0.0	6/14/70	1.5	57.0	0.0
5/7/70	1.2	56.6	0.0	6/15/70	1.5	50.2	0.0
5/8/70	1.2	55.8	0.0	6/16/70	1.6	49.0	0.0
5/9/70	1.3	54.8	0.0	6/17/70	1.6	50.5	0.0
5/10/70	1.2	53.6	0.0	6/18/70	1.3	48.1	0.0
5/11/70	1.0	53.8	0.0	6/19/70	1.1	46.5	0.0
5/12/70	1.5	54.2	0.0	6/20/70	1.0	43.9	0.0
5/13/70	1.3	57.1	0.0	6/21/70	1.0	28.9	0.0
5/14/70	1.4	52.9	0.0	6/22/70	1.3	28.1	0.0
5/15/70	1.3	57.6	0.0	6/23/70	1.0	22.7	0.0
5/16/70	1.5	54.7	0.0	6/24/70	1.0	26.8	0.0
5/17/70	1.7	53.9	0.0	6/25/70	1.3	0.0	0.0
5/18/70	1.6	53.8	0.0				

*One box is 90 pounds of fruit

TABLE B-2

AVERAGE ADDITION OF NUTRIENTS TO THE INFLUENT

Month 1969-70	Pounds Nitrogen	Pounds Phosphorus
November	151	101
December	230	184
January	821	99
February	571	64
March	328	21
April	381	22
May	629	28
June	592	26

TABLE B-2s

STATISTICAL ANALYSIS OF NUTRIENT ADDITION TO INFLUENT

	Data Points	Mean	Standard Deviation
Pounds Nitrogen Added, daily figures	217	488	301
Pounds Nitrogen Added, monthly figures	8	463	212
Pounds Phosphorus Added, daily figures	219	69	133
Pounds Phosphorus Added, monthly figures	8	68	54

TABLE B-3

AVERAGE ORGANIC AND SOLIDS ANALYSES OF INFLUENT AND EFFLUENT

Month 1969-70	BOD*		COD*		SS*		VSS*		pH	
	INF.	EFF.	INF.	EFF.	INF.	EFF.	INF.	EFF.	INF.	EFF.
November	452	2	975	41	104	15	93	15	9.3	7.6
December	704	16	2156	81	486	87	366	77	8.6	7.5
January	1715	34	3817	479	828	537	675	504	10.2	7.5
February	2408	23	7322	396	2585	618	1977	453	9.6	7.7
March	1323	32	3775	386	485	626	425	558	7.7	7.5
April	926	9	2625	83	250	181	204	152	8.2	7.4
May	1230	22	3579	154	329	225	281	210	8.6	7.3
June	1104	5	4481	119	462	122	435	116	8.1	7.7

*mg/l

TABLE B-3s

STATISTICAL ANALYSIS OF INFLUENT AND EFFLUENT
ORGANIC AND SOLIDS CONCENTRATIONS

		Data Points	Mean	Standard Deviation
BOD*	INF.	67	1290	869
Daily Figures	EFF.	56	19	20
BOD*	INF.	8	1245	598
Monthly Averages	EFF	8	18	11
COD*	INF.	67	3685	2312
Daily Figures	EFF	67	234	275
COD*	INF.	8	3591	1755
Monthly Averages	EFF.	8	217	162
SS*	INF.	62	705	830
Daily Figures	EFF.	63	324	409
SS*	INF.	8	691	743
Monthly Averages	EFF.	8	301	235
VSS*	INF.	62	568	649
Daily Figures	EFF.	63	282	376
VSS*	INF.	8	557	561
Monthly Averages	EFF.	8	261	198
pH	INF.	67	8.9	1.8
Daily Figures	EFF.	67	7.5	0.3
pH	INF.	8	8.8	0.8
Monthly Averages	EFF.	8	7.5	0.1

*mg/l

TABLE B-4

ACTIVATED SLUDGE PROCESS LOADING RATES

Date	BOD mg/l	Flow Rate MGD	Avg.MLSS mg/l	lbs.BOD/ lbs.MLSS
12/22/69	502	1.1	4946	0.07
12/28/69	400	1.0	3750	0.04
12/29/69	590	1.3	3850	0.07
12/30/69	1175	1.3	4400	0.12
1/6/70	770	1.2	4325	0.07
1/8/70	540	1.4	4180	0.06
1/14/70	1200	1.7	5925	0.11
1/15/70	1620	1.6	5700	0.15
1/16/70	3840	1.4	6600	0.27
1/19/70	1250	1.5	5850	0.11
1/20/70	1740	1.6	5460	0.17
1/21/70	975	1.5	5180	0.10
1/26/70	2460	1.6	5600	0.23
1/27/70	2760	1.8	4370	0.38
2/2/70	4250	1.3	3200	0.58
2/5/70	600	1.7	3925	0.09
2/9/70	2460	1.1	5000	0.18
2/10/70	2850	1.0	5500	0.17
2/11/70	1935	0.9	5925	0.10
2/16/70	2070	1.6	4600	0.24
2/17/70	1710	1.0	5400	0.11
2/23/70	3300	1.2	4870	0.27
2/24/70	2510	1.3	5000	0.22
3/3/70	1100	1.4	4120	0.12
3/4/70	2100	1.3	4310	0.21
3/5/70	2135	1.5	4170	0.26
3/9/70	540	1.2	4210	0.05
3/10/70	2500	1.4	4175	0.28
3/11/70	2165	1.4	4280	0.24
3/16/70	155	0.4	3800	0.01
3/17/70	505	1.1	3990	0.05
3/18/70	810	1.2	4020	0.08
4/14/70	720	1.4	2980	0.11
4/15/70	650	1.3	3565	0.08
4/16/70	1500	1.2	3900	0.15
4/20/70	850	1.3	4020	0.09

TABLE B-4
(Continued)

ACTIVATED SLUDGE PROCESS LOADING RATES

Date	BOD mg/l	Flow Rate MGD	Avg.MLSS mg/l	lbs.BOD/ lbs.MLSS
4/21/70	1050	1.5	4150	0.13
4/22/70	1300	1.4	4235	0.14
4/27/70	600	1.3	4620	0.06
4/28/70	760	1.4	4550	0.08
4/29/70	900	1.5	4640	0.10
5/4/70	770	1.5	4335	0.09
5/5/70	2110	1.1	4470	0.17
5/11/70	1300	1.0	4635	0.09
5/12/70	900	1.5	4560	0.12
5/13/70	960	1.3	4575	0.08
5/18/70	1320	1.6	3960	0.18
5/19/70	1250	1.5	3890	0.16
6/2/70	1500	1.4	3955	0.18
6/3/70	840	1.4	3895	0.10
6/9/70	1300	1.6	4495	0.15
6/10/70	1690	1.6	4500	0.20
6/16/70	950	1.6	4420	0.11
6/17/70	750	1.6	4550	0.09
6/23/70	900	1.0	4635	0.06
6/24/70	900	1.3	4300	0.09

TABLE B-4s

STATISTICAL ANALYSIS OF ACTIVATED SLUDGE
PROCESS LOADING RATES

	Data Points	Mean	Standard Deviation
BOD, mg/l	56	1416	873
Flow Rate, mg/l	56	1.3	0.2
Avg. MLSS, mg/l	56	4526	705
lbs BOD/lbs MLSS	56	0.14	0.09

TABLE B-5

AEROBIC SLUDGE DIGESTER

Month 1969-70	Influent Solids (%)	Effluent Solids (%)	Effluent Sludge (1000 gal/day)
December	--	1.7	47
January	1.23	2.1	56
February	0.7	2.2	81
March	0.6	1.5	41
April	1.0	1.9	24
May	0.8	3.7	51
June	0.7	3.1	53

TABLE B-5s

STATISTICAL ANALYSIS OF AEROBIC SLUDGE DIGESTER

		Data Points	Mean	Standard Deviation
Solids % Daily Figures	INF.	52	0.93	0.32
	EFF.	64	2.27	0.81
Solids % Monthly Figures	INF.	6	0.84	0.21
	EFF.	7	2.31	0.74
Effluent Sludge Daily Figures		184	51	35
Effluent Sludge Monthly Figures		7	50	16

TABLE B-6

CENTRIFUGE PERCENT SOLIDS

Actual Date	Influent (%)	Centrate (%)	Cake (%)	Influent Feed Rate (gpm)	R P M	Pool Depth Inches	Coagulant Type	Coagulant Feed Conc. (%)	Coagulant Feed Rate (gpm)	Disp. H_2O (gpm)	Recovery (%)
12/8/69	1.4	0.65	2.26	10-15	1600	2.6	None	0.0	0.0	0.0	75
12/9/69	1.0	0.05	1.84	10-15	1600	2.6	None	0.0	0.0	0.0	97
12/11/69	1.1	0.07	4.7	20-25	2100	2.6	None	0.0	0.0	0.0	95
12/12/69	1.3	0.02	6.5	20-25	2100	2.6	None	0.0	0.0	0.0	98
12/29/69	1.4	0.64	4.6	20-25	1750	2.5	None	0.0	0.0	0.0	63
1/5/70	2.0	1.1	4.7	20-25	1750	2.5	None	0.0	0.0	0.0	58
1/8/70	1.6	0.81	4.6	20-25	1750	2.5	None	0.0	0.0	0.0	60
1/9/70	1.7	0.89	4.9	20-25	1750	2.5	None	0.0	0.0	0.0	58
1/14/70	1.6	0.72	3.7	20-25	1750	2.5	Non	0.0	0.0	0.0	68
1/14/70	1.6	0.67	4.8	20-25	1750	2.5	None	0.0	0.0	0.0	67
1/14/70	1.8	0.89	4.2	20-25	1750	2.5	None	0.0	0.0	0.0	64
1/15/70	1.7	1.1	4.1	20-25	1750	2.5	None	0.0	0.0	0.0	48
1/18/70	1.9	1.1	6.6	40	2100	2.5	None	0.0	0.0	0.0	50
1/19/70	1.5	1.3	6.4	40	2100	2.5	None	0.0	0.0	0.0	16
1/20/70	3.0	1.9	5.8	40	2100	2.5	Nalco 607	0.5	0.5	0.0	54
1/21/70	1.6	1.1	4.8	40	2100	2.5	Nalco 607	0.5	0.5	0.0	40
1/22/70	1.4	0.68	2.5	40	2100	2.5	Nalco 607	0.5	0.5	0.0	70
1/22/70	1.4	0.20	3.7	35	2100	2.5	Nalco 607	0.25	0.25	0.0	90
1/23/70	1.6	0.73	2.7	35	2100	2.5	Nalco 607	0.25	0.25	0.0	74
1/25/70	1.5	0.86	6.1	35	2100	2.6	None	0.0	0.0	0.0	49
1/26/70	1.6	1.0	7.1	35	2100	2.6	None	0.0	0.0	0.0	43
1/27/70	1.8	1.3	8.4	20-25	2100	2.6	None	0.0	0.0	0.0	33
1/28/70	0.0	1.2	7.4	20-25	2100	2.8	None	0.0	0.0	0.0	35

TABLE B-6
(Continued)

CENTRIFUGE PERCENT SOLIDS

Actual Date	Influent (%)	Centrate (%)	Cake (%)	Influent Feed Rate (gpm)	R P M	Pool Depth Inches	Coagulant Type	Coagulant Feed Conc. (%)	Coagulant Feed Rate (gpm)	Disp. H_2O (gpm)	Recovery (%)
1/28/70	2.1	1.4	7.2	20-25	2100	2.8	Nalco 607	0.5	0.8	0.0	41
1/29/70	2.1	0.82	7.6	20-25	2100	2.8	Nalco 672	0.5	0.25	0.5	68
1/30/70	1.8	0.97	6.9	20-25	2100	2.8	None	0.0	0.0	0.0	53
1/30/70	1.9	0.28	6.2	20	2100	2.8	Cat Floc	5.0	0.9	5.0	89
1/30/70	1.9	0.58	5.7	20	2100	2.8	Cat Floc	5.0	0.25	5.0	77
1/31/70	1.7	0.71	6.6	20	2100	2.8	Cat Floc	5.0	0.25	5.0	65
2/2/ 70	2.2	0.97	6.7	20	2100	2.8	Cat Floc	1.0	0.57	0.8	65
2/2/70	2.1	0.78	6.6	20	2100	2.8	Cat Floc	1.0	0.57	2.0	71
2/2/70	2.1	1.0	6.4	20	2100	2.8	Cat Floc	0.38	0.73	2.2	60
2/2/70	2.1	1.2	6.3	20	2100	2.8	Cat Floc	0.38	0.57	2.2	52
2/5/70	1.6	0.86	6.3	20-25	2100	2.8	Cat Floc	0.50	0.80	5.0	53
2/6/70	1.6	0.99	7.9	20-25	2100	2.6	None	0.0	0.0	0.0	43
2/7/70	1.9	1.3	6.8	20-25	2100	2.6	None	0.0	0.0	0.0	39
2/8/70	1.1	0.88	6.3	20-25	2100	2.6	None	0.0	0.0	0.0	23
2/10/70	1.5	0.87	6.3	20-25	2100	2.6	None	0.0	0.0	0.0	48
2/11/70	1.4	0.62	6.0	20-25	2100	2.6	None	0.0	0.0	0.0	62
2/12/70	1.4	0.65	5.7	20-25	2100	2.6	None	0.0	0.0	0.0	60
3/4/70	1.2	0.52	2.3	20-25	2100	2.6	None	0.0	0.0	0.0	73
3/4/70	2.0	0.82	2.9	20-25	2100	2.6	Cat Floc	0.76	0.75	5.2	82
3/4/70	1.3	0.10	2.5	20-25	2100	2.6	Cat Floc	0.76	0.86	5.2	96
3/4/70	1.4	0.13	2.4	20-25	2100	2.6	Cat Floc	0.76	0.63	5.2	95

TABLE B-6
(Continued)

CENTRIFUGE PERCENT SOLIDS

Actual Date	Influent (%)	Centrate (%)	Cake (%)	Influent Feed Rate (gpm)	R P M	Pool Depth Inches	Coagulant Type	Coagulant Feed Conc. (%)	Coagulant Feed Rate (gpm)	Disp. H_2O (gpm)	Recovery (%)
3/4/70	1.4	0.15	2.7	20-25	2100	2.6	Cat Floc	0.76	0.47	2.5	94
3/4/70	1.3	0.26	2.6	20-25	2100	2.6	Cat Floc	0.90	0.80	5.0	88
3/5/70	1.1	0.18	2.3	20-25	2100	2.6	Cat Floc	0.50	0.63	5.0	90
3/5/70	1.6	1.1	2.9	20-25	2100	2.5	None	0.0	0.0	0.0	50
3/5/70	1.4	0.67	3.0	20-25	2100	2.5	Cat Floc	0.70	0.60	4.1	67
3/5/70	1.5	0.30	3.4	20-25	2100	2.5	Cat Floc	0.70	0.86	4.0	87
3/5/70	1.2	0.35	2.6	30	2100	2.5	Cat Floc	0.70	0.86	7.8	81
3/6/70	1.1	0.37	2.3	30	2100	2.5	Cat Floc	0.50	0.63	8.1	79
3/6/70	0.82	0.45	2.2	30	2100	2.5	Cat Floc	0.50	0.60	8.1	56
3/6/70	1.2	0.50	2.1	30	2100	2.5	Cat Floc	0.50	0.27	7.7	76
3/6/70	1.2	0.34	2.3	30	2100	2.5	Cat Floc	0.50	0.73	8.6	84
3/10/70	1.6	1.2	3.4	30	2100	2.5	None	0.0	0.0	0.0	38
3/10/70	1.8	0.96	2.8	30	2100	2.5	Hercules	0.50	0.86	7.0	71
3/10/70	1.9	1.2	2.8	30	2100	2.5	Hercules	0.50	0.50	7.0	64
3/12/70	1.6	0.54	2.7	30	2100	2.5	Hercules	0.50	0.70	7.0	82
3/12/70	1.6	1.1	2.7	30	2100	2.5	Hercules	0.50	0.37	7.0	52
3/13/70	2.0	1.9	3.6	30	2100	2.5	None	0.0	0.0	0.0	10
3/13/70	1.5	1.0	5.2	30	2100	2.5	None	0.0	0.0	0.0	41
3/13/70	1.5	0.89	2.2	30	2100	2.5	Betz 1150	0.25	0.73	8.0	68
3/13/70	1.7	1.0	2.2	30	2100	2.5	Betz 1150	0.25	0.37	8.0	75
3/13/70	1.6	1.0	2.2	30	2100	2.5	Betz 1150	0.25	0.18	8.0	68

TABLE B-6
(Continued)

CENTRIFUGE PERCENT SOLIDS

Actual Date	Influent (%)	Centrate (%)	Cake (%)	Influent Feed Rate (gpm)	R P M	Pool Depth Inches	Coagulant Type	Coagulant Feed Conc. (%)	Coagulant Feed Rate (gpm)	Disp. H_2O (gpm)	Recovery (%)
3/17/70	1.7	1.3	4.4	30	2100	2.5	None	0.0	0.0	0.0	33
3/17/70	1.7	1.3	2.7	30	2100	2.5	Betz 1150	0.50	0.73	7.5	45
3/18/70	1.5	1.2	2.2	40	2100	2.5	None	0.0	0.0	0.0	43
3/18/70	1.5	0.8	2.3	40	2100	2.5	Cat Floc	1.4	0.96	8.7	65
3/18/70	1.6	0.9	2.3	40	2100	2.5	Cat Floc	1.4	0.96	8.0	58
3/18/70	1.5	0.9	2.3	40	2100	2.5	Cat Floc	1.4	0.92	8.0	50
3/18/70	1.8	1.0	2.3	40	2100	2.5	Cat Floc	1.4	0.92	8.0	73
3/18/70	1.7	1.1	2.2	40	2100	2.5	Cat Floc	1.4	0.75	9.0	55
3/19/70	1.7	1.1	2.1	40	2100	2.5	Cat Floc	1.4	0.60	9.0	56
3/19/70	1.7	1.2	2.2	40	2100	2.5	Cat Floc	0.90	0.81	7.3	53
3/19/70	1.8	1.2	2.2	40	2100	2.5	Cat Floc	0.90	0.90	6.0	60
3/19/70	1.5	0.9	2.4	30	2100	2.5	None	0.0	0.0	0.0	60
3/19/70	1.4	0.8	2.7	30	2100	2.5	Hercofloc 834.1	0.66	0.95	4.9	60
3/19/70	1.5	0.9	2.8	30	2100	2.5	Hercofloc 834.1	0.66	0.93	4.9	47
3/19/70	1.6	1.0	2.6	30	2100	2.5	Hercofloc	0.66	0.40	6.1	43
3/19/70	1.6	1.0	2.6	30	2100	2.5	Hercofloc	0.66	0.35	5.1	50
3/19/70	1.7	1.5	2.0	40	2100	2.5	Hercofloc				57
3/19/70	1.7	1.1	2.4	40	2100	2.5	Hercofloc	0.66	0.82	7.7	62
3/19/70	1.8	1.2	2.4	40	2100	2.5	Hercofloc	0.66	0.67	7.7	54

TABLE B-6

(Continued)

CENTRIFUGE PERCENT SOLIDS

Actual Date	Influent (%)	Centrate (%)	Cake (%)	Influent Feed Rate (gpm)	R P M	Pool Depth Inches	Coagulant Type	Coagulant Feed Conc. (%)	Coagulant Feed Rate (gpm)	Disp. H_2O (gpm)	Recovery (%)
4/14/70	1.8	1.2	13.8	20	2100	2.4	Cat Floc	0.50	0.75	6.0	50
4/15/70	1.5	1.5	7.0	30	2100	2.4	Cat Floc	0.50	0.75	9.0	35
4/16/70	2.3	1.1	14.0	35-40	2100	2.4	Cat Floc	0.50	0.75	9.0	56
4/17/70	1.5	1.0	10.5	20	2100	2.4	Cat Floc	0.50	0.75	9.0	36
4/21/70	1.5	1.1	12.9	20	2100	2.4	Cat Floc	0.50	0.75	9.0	29
5/5/70	1.4	1.3	5.8	20	2450	2.45	None	0.0	0.0	0.0	9
5/5/70	1.4	1.9	5.8	20	2450	2.45	None	0.0	0.0	0.0	5
5/6/70	0.5	0.2	5.0	20	2450	2.45	Cat Floc	0.5	0.5	5.0	62
5/8/70	1.2	0.6	4.9	29	2450	2.45	Cat Floc	0.5	0.5	5.0	32
5/8/70	1.3	0.9	4.7	38	2450	2.45	Cat Floc	0.5	0.68	5.0	25
5/8/70	1.4	0.7	5.8	9	2450	2.45	Cat Floc	0.6	0.20	5.0	32
5/8/70	1.5	0.9	5.1	22	2450	2.45	Cat Floc	0.5	0.36	5.0	29
5/12/70	1.0	0.5	4.7	20	2450	2.45	Cat Floc	0.5	0.5	5.0	55
5/13/70	0.8	0.4	4.3	20	2450	2.45	Cat Floc	0.5	0.5	5.0	55

APPENDIX C-PHOTOGRAPHS

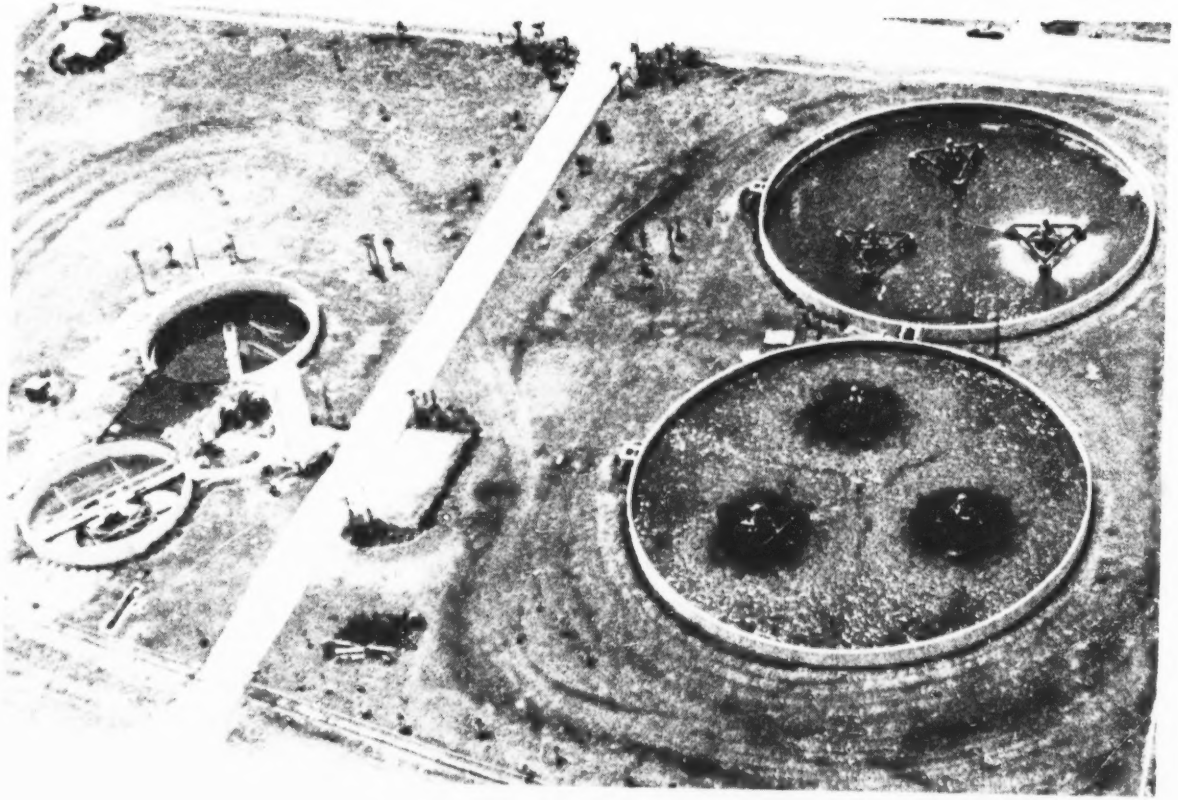

FIGURE C-1 - AERIAL VIEW OF WASTE TREATMENT PLANT

FIGURE C-2 - AEROBIC DIGESTER
(Modified Lime Treatment Unit)

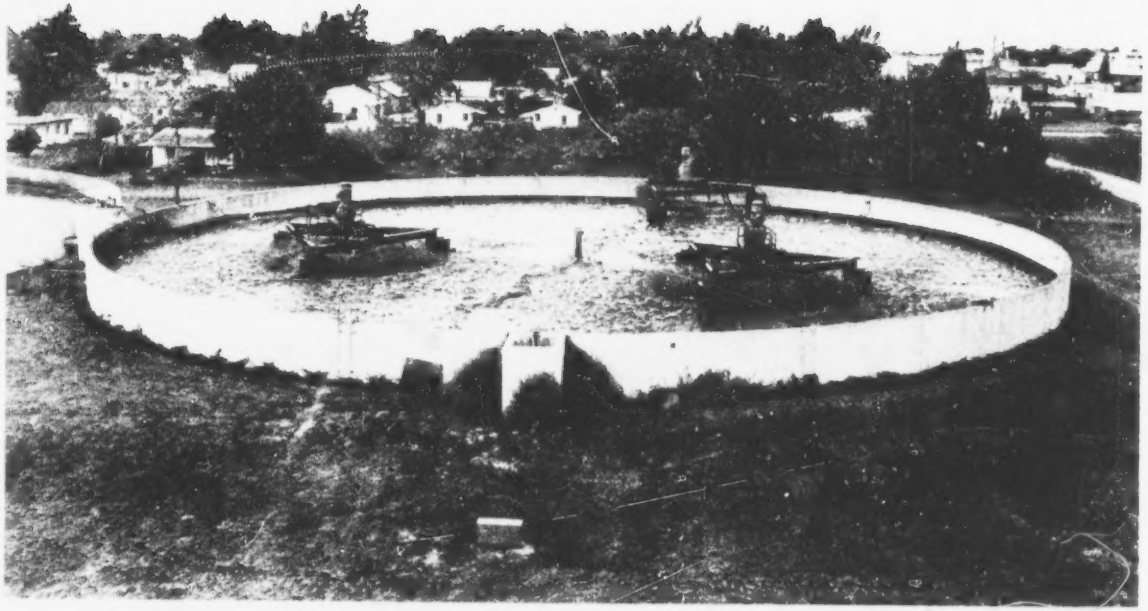

FIGURE C-3 - COMPLETE MIX ACTIVATED SLUDGE UNIT

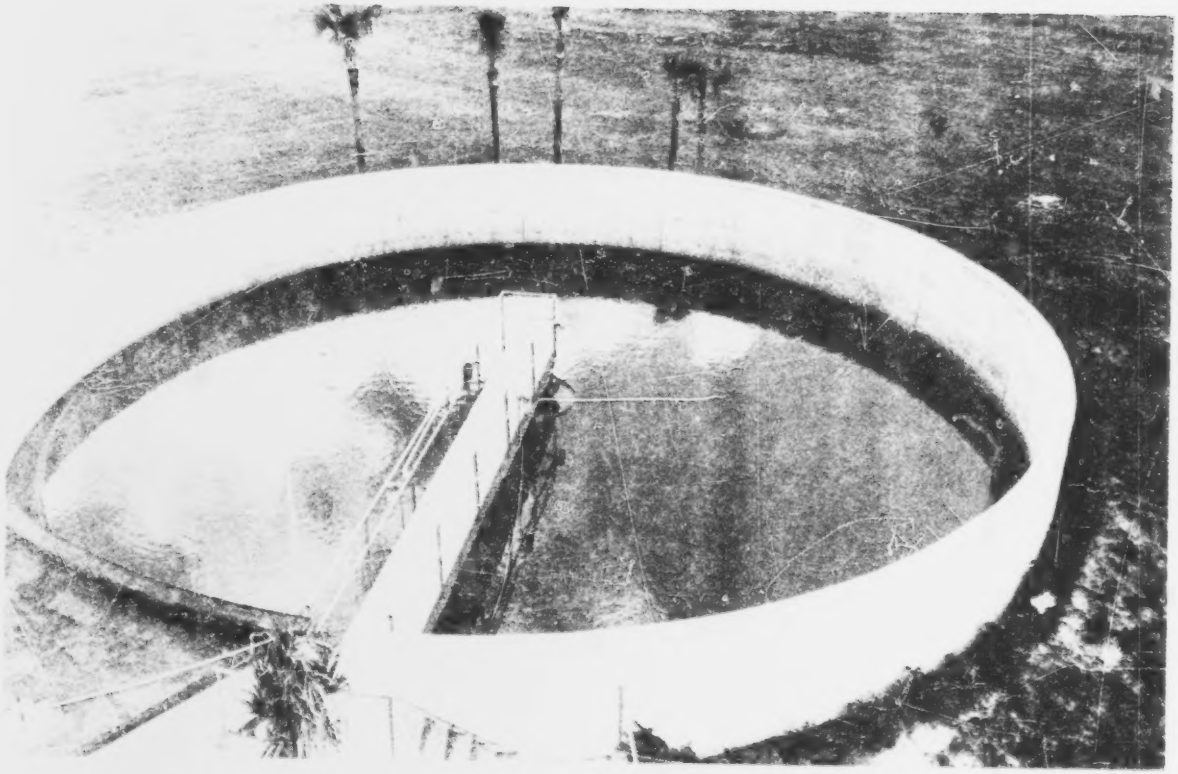

FIGURE C-4 - CLARIFIER

1 Accession Number	2 Subject Field & Group	SELECTED WATER RESOURCES ABSTRACTS INPUT TRANSACTION FORM
W	05D	

5 Organization

Winter Garden Citrus Products Cooperative
Winter Garden, Florida

6 Title

COMPLETE MIX ACTIVATED SLUDGE TREATMENT OF CITRUS PROCESSING WASTES

10 Author(s)

Jones, Richard H.

16 Project Designation

EPA, WQO Grant No. 12060 EZY

21 Note

22 Citation

23 Descriptors (Starred First)

*Citrus fruits, *Wastewater treatment, *Activated sludge, Estimated costs, Kinetics, Nutrient requirements, organic loading, seasonal

25 Identifiers (Starred First)

*Complete mix, *Lime Treatment, *Aerobic digestion

27 Abstract

A full-scale, complete mixed activated sludge treatment system effectively treats concentrated wastewater from the Winter Garden Citrus Products Cooperative. This process has a BOD reduction capability of 99 percent; but it produces 0.5 to 0.6 pounds of waste sludge per pound of influent BOD. The efficiency was reduced by periodic foaming and solids carryover in the effluent caused by the unscheduled discharge of orange oil and peel press liquor to the treatment plant.

Controlling the addition of nitrogen and phosphorus to the influent of the nutrient deficient wastewater effectively controlled effluent nitrogen and phosphorus concentrations.

Waste sludge was mixed with citrus peel and processed as a cattle feed additive in the existing facilities. The waste activated sludge represented approximately 1.5 percent of the total cattle feed production on a dry weight basis. Treatment plant effluent was reused for barometric leg and cooling water and was then discharged.

Abstractor: Richard H. Jones
Institution: Environmental Engineering, Inc.

WR:102 (REV. JULY 1969)
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